RIRDC

RURAL INDUSTRIES
RESEARCH & DEVELOPMENT CORPORATION

The New Rural Industries

A Handbook for Farmers and Investors

Edited by K.W. Hyde

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The New Rural Industries—A Handbook for Farmers and Investors

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Foreword

The pace of change in Australian agriculture is increasing rapidly in response to changes in world and domestic consumption patterns and the need to increase profitability and sustainability of its resource base. A major response to change has been the emergence of new industries often based on new and innovative technology.

I see this as a significant opportunity for farmers to develop their businesses in new directions. There will also be new opportunities for rural communities through the provision of new material inputs and services.

The sector has a small but growing group of business managers who are developing enterprises quite different to traditional industries like sheep, wheat, beef, sugar and dairy. These new industries are adding important diversity to our farm base reducing the sector's reliance on a few bulk products and associated markets.

Many of these new enterprises are based on our native flora and fauna while others are based on new market opportunities, be they in the export or domestic markets. Others are now developing because technology leaders have pushed out our knowledge boundaries, be they in growing, harvesting or processing. In our tropical north, industries are also emerging as we gain a better understanding of the requirements for intensive agricultural production in those areas.

What all these new rural industries have in common is that they are small, are more risky because they are new, and relevant information is not readily accessible. They are not like our mainstream industries where there is ready availability of information based on well tried technologies. The innovation and business like approach by many of these new enterprises also provides a model for more traditional farmers to follow.

This Handbook has been prepared to fill the information gaps on these new industries. Its aim is to provide a first step for those thinking about investing in new fields of agriculture. Each entry has a list of key contacts and references for follow-up. It is an essential reference for those with an interest in the new and emerging industries of Australian agriculture, be they farmers, investors, processors or research providers.

John Anderson
Minister for Primary Industries and Energy
December 1997

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Preface

This handbook has been produced by the Rural Industries Research and Development Corporation in response to the many requests received by the Corporation each week from farmers, investors, newspaper reporters, bankers, politicians, regional development advisers and students for up-to-date, factual information on the smaller, emerging and new rural industries.

It has been produced in collaboration with the Fisheries Research and Development Corporation which has sponsored the section on aquaculture industries. FIRDC and RIRDC have been jointly sponsoring research on aquaculture opportunities for Australia's inland waters.

Each chapter in the text has been researched and written by experts in the particular industry or product. They are people who are well known to RIRDC and FRDC for the quality of their research or their active involvement in the industry in question. Each chapter has also been reviewed by industry practitioners, researchers and by a RIRDC–FRDC review panel.

The handbook addresses the most frequently asked questions about the market prospects and production–processing requirements for some ninety smaller or prospective new rural industries. It is a factual text which gives a 'warts and all' assessment of the strengths, weaknesses, opportunities and threats for each industry.

This introduction for prospective investors in, or the student of new industries is intended as an overview, but guidance is given to more detailed information—each chapter lists key references and contacts for follow-up information.

Prospective investors and industry advisers are encouraged to use the text as an initial reference and are advised to undertake more detailed personal follow-up investigation of each industry and its suitability to regional and personal circumstances. While every effort has been made to ensure the accuracy and currency of the information in each chapter at the time of writing, the markets are changing and new information is becoming available regularly.

The production and editing of the handbook has been managed by Keith Hyde, a former Managing Director of the Rural Industries Research and Development Corporation, member of the Australian Special Rural Research Council and researcher and adviser on new industries for rural Australia.

The Rural Industries and Fisheries Research and Development Corporations thank all the specific authors and the many behind the scenes contributors to 'the publication. In addition, we would like to acknowledge the editorial assistance, design and layout work on the publication by Ed Highley and his staff at Arawang.

Peter Core
Managing Director
RIRDC

December 1997

Success factors for developing new rural industries

Keith Hyde

Introduction

Australian farmers have a long and successful history of developing new animal and plant products into new industries. The search for new animal and plant products started with the first European settlers in Port Jackson over 200 years ago. They brought cattle, sheep, grains and vegetable crops with them but they soon found that the breeds and varieties to which they were accustomed in Europe were not well adapted to the very different climate and the poorer soils of New South Wales.

The native plants and animals were unfamiliar the European settlers. The plants and animals of interest for food or fibre were relatively sparse and were not farmed or cultivated by the Aboriginal inhabitants. The animals were wild, untamed species and were not conducive to the farming systems known to the Europeans.

The new settlers therefore turned to other parts of the world with which they were familiar—the Americas, India, South Africa and southern Europe—as a source of animal and plant species for the new colony. The search for new species and the subsequent trials were relatively ad hoc. They were guided by trial, error and an imperative to succeed to be able to feed and clothe a growing colony.

Two hundred years later, Australians continue to scour the world for new plant and animal species which they can develop into new industries. Recent introductions include Boer Goats from South Africa, Alpacas from South America (via the USA), Atlantic Salmon from Europe, Cashews from Brazil via India and grain legumes from the Indian sub-continent.

There have been many successes and failures in the interim period. The successful introduction of Merino sheep from Spain and the development of new wheat varieties more suited to Australian conditions by William Farrer are well known. However, there are numerous other successes which we now take for granted, for example: apples, bananas, citrus, cotton, the Friesian dairy cows which produce most of Australia's milk, melons, sugar cane, trout, *Bos indicus* cattle and zucchinis.

South African proteas have been successfully developed for Australian conditions.

About the author

Keith Hyde has been actively involved in the development of new rural industries throughout his career initially in the Northern Territory and more recently during 12 years with the Rural Industries Research and Development Corporation and its predecessors.

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The following chapters reflect the continued search for new plants and animals around the world to develop into new industries for Australia. The staff of State departments of agriculture, the CSIRO and Australia's universities have methodically searched for and developed new crop, animal and pasture species. There are also many personal efforts by farmers and nurserymen. Commercial companies have been active in the introduction of many new horticultural and grain crops from Europe and North America.

There has also been renewed interest in Australian species such as abalone, barramundi, crocodiles, emus, kangaroos, marron, tea tree oil and wildflowers which are being developed into commercial industries.

Australians are not unique in their interest in new industries. It is a global phenomenon dating back to the earliest days of civilisation as we know it. The earliest global explorers sought fertile new lands, minerals, new crops, animals and their products to add to their personal and national wealth, standard of living and knowledge. The rich mixture of animals and crops which makes up the farming systems of any country has a diverse history. It has been acquired and developed through the millennia. The processing and marketing systems which transform and transport the farm commodities into consumer products have also developed around the world over many generations.

Why develop new industries?

Australians no longer have an imperative to produce more food for an expanding domestic population, or to expand production for clothing or shelter, for the Australian population is very well provided for in all three areas. Similarly, Europeans and North Americans are well fed, well clothed and well housed. There are notable and distressing exceptions to this generalised conclusion on each continent, but they do not compare with the continued malnutrition and poor housing of many parts of Africa and Asia.

Why then do individuals and governments on all continents, and also the many international agencies, continue to investigate and to develop crops and animals into new industries?

The priority for many countries, especially in Africa and Asia, continues to be focused on increased production of food supplies, on fibre products for clothing or housing, on generating employment for a growing population, and on increasing national wealth and standard of living.

However, Australia is in a far more fortunate position in these last years of the twentieth century. Australia's industry development and personal imperatives include:

- ***To create employment opportunities,*** particularly in rural areas and for young Australians. Australia's cities continue to grow and its rural towns continue to shrink. Government agencies and business continue to reorganise and to rationalise their work forces. The result has been the closure or downsizing of many country banks, hospitals, advisory services, service suppliers and associated support facilities, the loss of previous jobs for older residents and fewer jobs for younger people. At the same time, farm and regional townspeople want to create new opportunities for themselves and their families. They are investigating alternative farm enterprises and new business structures to generate economies of scale. The maintenance of family ties is regarded highly in most rural areas.

- ***To develop more sustainable farming systems.*** Most Australian farmers are very conscious that, while their current farming systems were developed with the best intent and based on the best available knowledge, they are not sustainable in the long term. They are very conscious of rising water tables, salinity, increasing soil acidity in some areas, declining soil structure, pest and disease problems. They are searching for: less exploitative farming systems; reduced use of synthetic fertilisers and chemicals for pest and disease control, both of which are expensive and can result in undesirable residues; alternative crops and animals to incorporate into their farm rotations; and for alternatives to diversify their income bases. Aquaculture industries are being developed to provide supplies of product in the face of declining stocks from the wild.

- ***To improve our own and our neighbours' standard of living.*** Satellite communications, the Internet, global news services and overseas travel have brought international commodity markets into every farm business. The debate is about the impact of exchange rate movements, changes in quarantine controls and the US Farm Bill. Australian farmers are very conscious that they operate in global market environment and that to remain competitive they have to be at the cutting edge of new technologies, knowledgable of global market trends and actively developing market opportunities. There is also acceptance within the Australian community that our neighbours in Africa, Asia and the Pacific can be helped to develop their standard of living and international business prospects to the mutual benefit of all countries.

Location is most important for new aquaculture industries, especially to provide ready access to assured supplies of quality water.

- ***To fulfil an innate personal yearning to do something different or better.*** For some people the challenge is to climb the next highest mountain, for others it is to fulfil a life dream, to help another person, for interest, for self-fulfilment, to be competitive, or to demonstrate one's worth to another person. There are many and varied reasons why people take up the challenge of a new business at various stages in their lives. Most of them relate to self-fulfilment and feeling good about oneself. For some people a hobby opens up as a business opportunity. For others it is a driving ambition to be successful, to solve a problem or to be proven as good as, or better, than another person.

Rationalist economic arguments suggest that individuals, companies and countries should focus on their existing strengths, build on their existing industries or products and that investment of time and money in alternatives is economic folly. Policies and activities based on such arguments have their place, but the arguments also require careful interpretation. The narrowest interpretations would have precluded the development of the motor car, television and the Japanese electronics industry. They could lock a country or a company into a very narrow and vulnerable economic path. Investigation of alternatives and pursuit of a natural curiosity have opened up many new rural business opportunities in Australia and around the world.

Australian natives tea tree and abalone are being developed collaboratively between industry and government research agencies.

Key success factors

After some two hundred years of experimentation, trial, error, some outstanding successes and also many failures in the history of the development of new industries, one might reasonably expect there to be some consensus on the key success factors. But there is not. On one hand, there is considerable evidence pointing to the importance of key individuals, genetic material and production or processing technologies which can be transferred from other parts of the world, opportunities created by population changes, crop failures resulting from drought, floods or diseases, or the actions of governments to open up new lands, promote a new crop or animal product or to ban others. On the other hand, others argue that industry success is more serendipitous and not related to any one factor. This latter group argues against 'picking winners', but that is just what any individual farmer, processor, researcher or government does when choosing a new crop or animal product.

The Rural Industries Research and Development Corporation and the Fisheries Research and Development Corporation have taken a keen interest in the development of new industries as part of their core business. The corporations and their predecessors have sponsored research on new industries since 1955. In that time they have seen many prospects develop into new businesses and new industries. There have also been some failures—prospective opportunities which have been pursued into blind alleys. The 'failures' also offer lessons for the future and have been reviewed in corporation studies. Their experience has been reflected in the product and industry analyses which follow in this handbook. Some of the key success factors include the following:

The champion. A key person in any new business or industry is the new business entrepreneur or industry champion. This person either directly or indirectly provides the vision, the drive, the energy, the ideas, the commitment and the plan to turn the vision into reality.

Too often the new business entrepreneur is thought of as a smart-suited business person, and all too often this person is equated with the people who trade scrip on the stock exchange. However, entrepreneurs are found in many walks of life: on farms, in business, in research and in community service. Key features of the entrepreneur who develops new business are:

- the ability to spot an opportunity and the motivation to act to realise opportunities;
- they are competitive and either profit or achievement driven;
- they are willing to take risks, but they are usually calculated risks for which they have risk management strategies—successful entrepreneurs are not reckless;
- they are effective planners and managers of the resources available to them. Successful entrepreneurs are very adept at marshalling all the resources necessary to make the venture successful. They are also very good at contingency management and managing problems if some resources are not available as originally planned; and
- successful entrepreneurs are very committed, they have plenty of stamina and are prepared to put in the hard work to ensure the venture is a success.

You will be able to identify many plant breeders, engineers, farmers and others who do not characterise themselves as 'entrepreneurs', but have all the above success factors.

Market focus. The second winning factor in successful new industries and businesses is that they are market focused. To achieve this market focus the people involved:

- undertake considerable research on their market. In many instances the market research is undertaken first-hand by the principal or principals involved. Information from one source is also checked with another source. The strengths and weaknesses of competitors in the market are also researched.
- they have close contact with their customers and they share critical information with key people in the market chain;
- good communication is a key feature of successful new industries.

Other factors, which have been important for some industries have been the name or 'brand' of the product, promotion of clean, green or fresh characteristics, exploitation of off-season opportunities and the development of niche markets. Guidelines for doing your own market research are presented in the next chapter.

Location , location, location, location. Most new crop and animal products are produced around the world well away from their origins. Many crops and most animals have been very resilient in their ability to adapt to new conditions. They do have preferences, however, under which they will be less susceptible to pests and diseases or have higher productivity.

- The first location factor is *climate*. Most crop and animal species have temperature, humidity, wind and water preferences. Many plants have a daylength or a temperature requirement for onset of flowering or for fruit set.
- The second location factor to consider is *soil type*. While animals are less dependent on soil type, soil type often determines the quality of the pasture and hence animal growth rates. Most plants have soil type preferences, but not all plants have a preference for deep rich soils. As indicated in the following chapters many Australian wildflowers prefer poorer sandy soils.
- The third critical location factor is topography and this factor is coupled with aspect. Topography influences cold air or soil water drainage, the suitability of the site for machinery access or for irrigation. The site aspect can influence the exposure of a crop to either beneficial or deleterious winds. It can also influence site temperatures.
- The fourth location factor is access to water for irrigation or aquaculture ponds. Aquaculture requires an assured supply of good quality water.

Other important location factors include access to community infrastructure, service supplies and access to markets.

Transferable technologies. The production and processing systems for any industry embody a complex array of technologies and knowledge which, for older industries, has been built up over many generations. The common breeds and varieties used in food and fibre production around the world, for example wheat and dairy cows, are the result of many centuries of selection for product quality and productivity, pest and disease resistance and temperament, etc. New technologies and research methods can expedite productivity enhancements, but the experience indicates that anyone with an interest in new industries should have a healthy respect for time and technology factors. Some of the key factors are:

- whether the product is already produced in another part of the world and whether the technologies associated with production in that location are readily transferable or adaptable to Australian conditions. The economics of production in Australia often require higher yields, quality improvement and mechanisation for profitability. However, there will have been some selection processes and there will be a body of knowledge associated with the production and processing if the product is produced, even under quite basic conditions, in another part of the world;
- traditional use may facilitate market access, market development and also alleviate the need for costly food safety research and registration as a new food product;
- if new technologies are required, are they simple or are they complex and might they be both expensive and time consuming to develop? Simple technologies can be readily copied and expose the new business to competition. Complex technologies, on the other hand, can provide a protective shield around the new business;

Cashew industry development champion Peter Shearer discusses a high yielding selection with the author.

- technologies, skills and equipment which can be shared within the farm or manufacturing business assist the development of new products. For example, new grain legumes which make use of existing harvesting equipment and improve crop rotations on broadacre farms have been quickly adopted.

Financial management. The financial resources available to the new venture have been a key success factor in most if not all case studies reviewed by the Corporation. The people involved in successful new industry ventures have:

- adequate initial financial resources at their disposal for capital equipment, purchase of stock, development of land and for initial operating expenses. Very few ventures can afford the cost of borrowing funds at the market interest rates. Funds borrowed at lower interest rates against the operators business as a whole have been successful in many instances. However, individual choosing this approach must alway weigh up the relative risks and opportunities.
- new ventures do have a significant demand for operational funds over an extended period before they become profitable and this demand must be sustained from capital resources or from cash flow provided by other enterprises. The successful new venture must be able to sustain some interruption in cash flow, ie. development must be able to be put on hold, if for some reason cash flow from other activities is lower than expected.

Transferable technologies, more sustainable systems and integration with existing farm activities have been keys to the adoption of grain legumes and oilseeds on Australian farms.

- Government incentives and tax concessions, and particularly the latter, are important to the new industry development, but new industries are not built on incentives or concessions alone. They must have some inherent competitive advantages and prospects of independent profitable operation.
- joint venture arrangements can provide capital, expertise materials and/or market linkages for the new venture and all need to be considered. However, there are downsides of joint ventures which also need to be considered, ie. what happens if one partner cannot meet their commitments, are the partners naturally compatible and do partners benefit in relative proportion to their input?

Style of operation. The style of operation or the *modus operandi* of the firm has also been identified as a success factor in new industry development, though the common characteristics were not so strongly identified as other success factor. A range of innovative styles were used in successful companies. These include:

- a strong profit and quality focus. This was a feature in most successful firms and new industries;
- a strategic long-term approach has been necessary for the development of most new industries. The Wood, Chudleigh and Bond research study, which is referenced below, indicates that new industry development is not for the faint-hearted. It can take 15 to 20 years to get a new industry prospect to the stage where it can be considered established;
- value adding and vertical integration have been important in some but not all instances. Secondary processing and direct marketing can yield high profit potential but there are also higher costs and market entry issues to be considered;
- the compatibility of the new venture with other farm or processing operations has been a key to success for many new products. Successful integration can result in more sustainable farming systems through improved rotations, soil improvement and breaks in pest and disease cycles, improved use of high cost equipment and improved use of time available to the business;
- imaginative marketing and trading arrangements have been a feature of several new industries;
- most new industries have been quick to adopt new technology. Their participants are technologically hungry and scour the world for best practices and innovative approaches. They are in direct contact with lead researchers and adopt technology well before the research journal papers are written;
- and once again the joint venture factor has been important for some industries.

Role of government. The final success factor is the role of government. Governments at local, State and Federal level have a significant influence over how business is conducted in Australia, in representing Australian interests in international forums and in provision of services such as roads, electricity, water supply, education, research and medical facilities.

- A key role for government has been to set the right economic environment for industry development. This was particularly important for new industry during the 1950s and 1960s and governments, both State and Federal, continue to search for the optimum economic environment to foster industry development, economic growth and new employment opportunities during the 1990s.

- Government agencies, and especially State departments of agriculture, the CSIRO and water supply authorities, have been a key source of information for new industry developers. Government agencies have traditionally kept better records than industry, they have also had some longstanding employees with whom you can discuss what did and what didn't work, and why.
- Governments have been key providers of R&D support in Australia.
- Finally, I reiterate the role of government as a provider of services and representation. Governments, both State and Federal, play a key role in market access negotiations.

In this paper, I have drawn together the key factors that have been observed to be important in the development of new industries in Australia over the past 40 years. I have drawn on several background studies and two review conferences supported by RIRDC and experience with many Australians who have been successful in their development of new ventures and new industries. The critical success factors, however, lie in the title of Geoff Cahill's 1993 reference 'Don't dream it, do it' and the many rural Australian who are making the development of new industries a new way of life for themselves.

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Marketing research for new industries

Rob Fletcher
Peter Twyford-Jones
Peter Blessing

Introduction

With new agricultural venture, it is human nature to be both curious and excited about producing something new. If the venture is intended to be commercial, rather than simply a hobby, it is important to be able to sell the product at a profit.

Selling the product from a new industry usually presents more problems than the production of the new product itself. Being able to produce a product means nothing if it cannot be sold, at an appropriate price. Developing the market poses the most significant challenges to the developers of new rural industries.

Marketing research for new industries

Evaluating the potential market is an important first step. This involves accurate predictions of the product's potential use(s), the target market, the potential prices, the distribution strategy, the market entry strategy and the manner in which a promotional plan would be organised.

Since the product is new and the industry itself is also probably new, there is very little relevant information readily available.

It is difficult to measure future demand and price levels for a new product. Developers of new products can often become emotionally attached to their 'offspring' and therefore can be unrealistic about the likely demand and price for it.

Although there are extensive marketing theories available for new manufactured products, this theory is often not relevant to market analysis for new agricultural industries.

This is because manufactured products are often adapted from existing products, are developed by large companies with large resources, only represent a small proportion of a firm's overall investment and can be produced on a large scale right from the initial production.

On the other hand, new agricultural products are often completely new, requiring novel production and processing technology. They are often developed by small companies or individuals with relatively limited financial resources, representing a large proportion of the firm's overall investment and may take years to achieve substantial production levels.

Primary producers in new industries need to ask the following key questions about their product:

- Can I sell it?
- How can I get it to market?
- Who will get in my way?
- How can I improve my information?

The framework of 'DOOR-Marketing'

The traditional approach to problem-solving in research is to rely upon an 'expert' to supply the answers, since an expert is the 'source of all wisdom'. In new industries, there is usually no such source of wisdom, since most problems are new ones.

The key to Do Our Own Research in Marketing (DOOR-Marketing) is action learning. For this approach to work, a number of producers, marketers and other interested parties need to pool their resources to solve the marketing questions given above.

They should together consider the following:

- What information do we need to know about our new industry and its product?
- Which of these issues relate to marketing and which to production?

The people involved in successful new industries undertake considerable personal research on their markets.

- What would be the priority for each issue?
- What would be the best sources of information?
- How will the information be gathered?

The marketing information needed includes:

- Is the product currently traded here or overseas?
- Where are the existing markets for the product?
- What type of markets are these, in terms of size?
- Description of the product
- What is the product used for—leading to identification of substitutes for the product and the nature of the substitution?
- Location of a target market for the intended new product
- Estimation of the possible market price, taking into account the possible price of substitutes, and import/export prices
- Identification of any limitations imposed by the market
- Description of the packaging required and the distribution mechanism available or required
- Estimation of the future demand (taking into account economic and demographic factors and factors which may affect this demand)
- Consideration of promotional strategies to be required

Once such information has been assembled, an analysis should be conducted to investigate the strengths, weaknesses, opportunities and threats (a SWOT analysis), assessing each of the following factors:

- Customer demand
- Competition
- Start-up costs
- Current market price
- Expected returns
- Industry trends
- Promotional strategies
- Distribution strategies
- Experience
- Resources
- Commercialisation procedure
- Production factors

The value of this approach to marketing research lies in the interaction between the participants of the group: cooperation between a number of interested individuals in solving difficult problems not only assists with the solving of the problem but also teaches a new approach which does not depend upon 'experts'.

Key messages

While it may be possible to overcome the difficulties in producing a new product, this is of no importance if the new product cannot be sold for a profit.

New industry development

DOOR-Marketing aims to assist those participants developing new agricultural industries with pre-feasibility marketing research for their industries. Such investigations are of primary importance in an overall strategy for new crop development, as follows:

1. the **proposal** of the new industry by those willing to commit themselves financially to such development;

2. the acknowledgment that new industry development is a **high risk** venture;

3. the recognition of the need to protect **intellectual property** rights;

4. the assessment of the **marketing potential** of the new industry product using all criteria published, identifying those criteria for which no information is available, this step has been targeted by **DOOR-Marketing**;

5. a **theoretical assessment of the production potential** of the new industry using all criteria published, identifying those criteria for which no information is available—large scale trialing is not recommended at this early stage of development;

6. the establishment of an **integrated development group** comprising producers, processors, distribution and marketing teams with research providers, initially in a **facilitation** role only;

7. agreement within this group of the **resource** requirements, expected outcomes, action plans to achieve them, and distribution of any profits;

8. the establishment of a process of project **monitoring** to identify and resolve problems quickly and efficiently;

9. the establishment of economic **benchmarks** and an agreement to abandon the project once these have not been met;

10. the establishment of a system of **review** to place on record the circumstances under which the project was successful or failed;

11. trial production for **trial marketing**;

12. trial production for **trial processing, packaging and transport**; and

13. **experimental production**.

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Key references

Hunter, M.L. and Hayes, G.W., Eds (1997). The DOOR Manual for Plant Nurseries. Queensland Department of Primary Industries. 105 pp. (Available from Growsearch, QDPI, P.O. Box 327, Cleveland, Qld 4163; (07) 3821 3784; $25 + $4 postage)

The key to the success of DOOR-Marketing is the collaboration and pooling of the resources of producers, processors and marketers to solve key market issues.

Animals

Alpacas

Chris Tuckwell

Introduction

Alpacas are one of four species of South American Camelids. Other members of the species are guanaco, llama and vicuña. All South American Camelids are closely related and related to other camel species, Bactrian (two- humped camel) and the dromedary (single-humped camel).

Alpacas and llamas were farmed by South American Incas for centuries before the Spanish invasion. They used sophisticated breeding and management programs to produce high-quality fibre for clothing and textiles. The destruction of the Inca empire brought the industry to an end. Their farming techniques had been passed on to successive generations through mnemonics, so the slaughter of the Incas meant that much of the knowledge was lost.

After the Spanish conquest, alpacas and llamas only survived in areas unsuited to the Spanish sheep and cattle, principally the Andean high plain or Altiplano. The world's alpaca industry scarcely existed until the 1860s. Its resurgence then lasted until Peru's political turmoil of the 1960s. A secondary resurgence began in the mid 1980s and continues today.

Australia's modern alpaca industry began in the late 1980s with the import of animals from Chile. Recent imports from Peru will add to the genetic base available in Australia.

Markets and marketing issues

The alpaca industry will remain speculative and based on the sale of breeding stock for the foreseeable future. Its future as a fibre-producing industry will be determined by the research now under way into its commercial production traits.

The most important factors that influence and determine the longevity of the alpaca industry include: (i) controlled, cooperative planning of industry development; (ii) market development; (iii) marketing program development; (iv) product development; and (v) processing technology development.

Without a sound knowledge of the size of the potential market for alpaca products it is difficult to predict prices, since the amount of product offered for sale is likely to change markedly. As a result, predictions about likely industry growth become more theoretical and are based simply on production potential.

Breeding stock currently sell for $10,000 - $30,000 per head. Australia has the potential to be the stud capital of the world. Currently steps are being taken to enable breeders to sell stock into the U.K., Europe, Canada and New Zealand.

The total production of Australian alpaca fibre in 1992 was 6,000 kg and in 1993 was estimated to be 10,000 kg. While the current contribution of the industry to the Australian economy is relatively small, it could become much more valuable.

Production requirements

Although many think that alpacas and llamas need high altitudes and harsh conditions, it is far from true. Various histories (fossil, Spanish) show that the animals evolved and were managed by the Incas on good pastures at low altitudes. Their survival in the high Andes since the mid-1500s is a matter of necessity rather than evolution.

The ideal production environments for alpacas appear to be similar to those for wool sheep. However, it is generally accepted that they need more dietary fibre than sheep. They can use dietary fibre more efficiently than sheep, so in areas of coarse fibrous feed alpacas appear to have the advantage.

Both alpacas and llamas are very adaptable and can withstand very harsh conditions. However, they do not tolerate high humidity well.

Breeds

Although alpacas and llamas are the species domesticated by the Incas and traditionally used for commercial production, researchers in Europe and South America are currently investigating the commercial possibilities of guanacos and vicuñas.

Alpacas are smaller than llamas and have been selected for fine-fibre production for at least 3,000 years. There are two distinct types: the suri alpaca and the huacaya. Suri alpacas are smaller animals that produce fine, lustrous fibre which crimps less and is soft handling. The fleece looks similar to that of Lincoln sheep and the fibre itself is similar to long mohair.

About the author

In 1978 Chris Tuckwell RDA RDAT graduated from the University of Adelaide's Roseworthy campus. Until 1996 he worked for the South Australian Department of Primary Industries (PISA). From 1990 he led New Animal Industries group. He now works for Rural Industry Developments Pty. Ltd. whose activities include: assistance with industry and enterprise development; the provision of technical and marketing advice; and research and extension programs. See *Key contacts* for address.

Suri type alpaca.

Huacaya alpacas comprise more than 90% of the total alpaca population. They produce a short, crimped fibre that is similar in appearance to that of Corriedale or merino sheep. Huacaya animals are generally bigger than suris and hardier.

Animal husbandry

Alpaca management is very similar to that of sheep. The best results for commercial fibre production come when alpacas have good-quality grazing and continual access to hay or other sources of fibre.

Unlike sheep, alpacas tend to urinate and dung at midden sites throughout a paddock rather randomly across the paddock. This means that contamination of pastures with internal parasite larvae is reduced and, with appropriate management, anthelmintic (drenching) requirements are much less than for sheep.

Male alpaca are usually at least two and often three years old before they can successfully inseminate a female. Female maturity is a function of age and body weight, but ideally females should be first bred at twelve months of age. Gestation in Peru ranges from 1.5 to 12.5 months so unless females are carefully managed, a long-term, average, annual reproductive rate for a population of female alpacas is unlikely to be greater than 70 to 75%. Improved nutrition in Australia has decreased gestation for some animals to 10.5 to 11.5 months.

Offspring are called cria. They are usually born before mid-afternoon on any day and rarely at night. They are weaned ideally at three months and not later than six months of age. The alpaca's reproductive physiology is different from other species and twins are very rare.

Aggressive or scared animals can react by biting and spitting. Although this is occasionally directed at handlers, it is more often directed at other alpacas.

The animals are shorn annually for their fleece. The timing of shearing should relate to other considerations such as the risks from grass-seed invasion. The animals are susceptible to sunburn if they are shorn during summer and insufficient fleece is left on. Alpacas have a soft, padded foot, similar to those of camels, which are likely to cause less damage to the soil structure, and subsequently the environment, than do sheep and cattle.

Huacaya type alpacas.

Key statistics

- An estimated 1500 animals were imported during 1996–97
- Approximately 1000 animals were exported in 1996 and 300 to 400 will be exported in 1997

	1992–93	1993–94	1994–95	1995–96	1996–97
No. of registered animals	4799	6983	8944	11290	14597
Estimated volume of fibre produced (kg)	7199	10475	13416	16935	21895
No. of registered owners	191	384	699	902	1105

Key messages

The future of a commercial Alpaca fibre based industry in Australia is dependent upon:

- determination of potential market and processor requirements;
- development of industry improvement plans which include the use of superior Peruvian genetics for the commercial good of the national industry; and
- continued development of fibre marketing plans for the commercial industry

Pests and diseases

Alpaca-to-alpaca infection by internal parasites is low because of their habit of creating middens (communal dung piles). Internal parasite infection risks increase if the animals are grazed with other species, particularly sheep. A parasite specific to Camelids exists in South America, but to date it has not been confirmed in Australia. The treatment for internal parasites is similar to that for sheep.

External mites, especially in the ears, can be a problem. Treatment usually involves Ivermectin-based products.

Cria are very susceptible to bacterial infection, particularly from Clostridial bacteria. Enterotoxaemia is a major disease of alpacas, particularly of cria. Routine vaccinations with commonly available 5 in 1 clostridial vaccine is important.

Alpacas also suffer from facial eczema. The best control is to farm the animals in areas not predisposed to the growth of the fungal spores responsible for the disease.

If Camelids are fed insufficient fibre, they suffer diarrhoea (scours). Treatment is simply to ensure there is enough fibre in the diet. Apart from that, alpacas need much the same feed and are susceptible to the same plant poisoning as sheep.

Harvesting, processing and marketing

Alpaca shearing requires two people. Animals are held in the catching pens of a normal shearing shed and are individually caught and brought out to the shearing board. The animal is restrained and rolled to the floor. Its rear and fore legs are connected to restrainers at the rear and head end of the animal respectively. Tension is place on the restrainers by adjusting the length of the cord attached to the restrainer.

The animal lies flat on the board with it legs extended in front and behind it. The fleece is removed with a normal hand piece (slow cutter speed) while the animal is held on the floor. After removal the fleece is skirted and classed in a similar manner to sheep fleece. It is mostly sorted on the basis of average fibre diameter, colour, length and type (huacaya, suri or hybrid).

In Peru most fibre is processed by large companies and sold on the international market. In Australia the industry's total production is still small and the majority of fibre sold goes to the high-value handicraft market.

The alpaca industry in Australia is still a speculative, breeding-based industry and profits are made from the sale of breeding animals. If alpaca populations increase without consideration of selection based on an objective assessment of commercially important traits, the future of the industry appears less certain. It will principally depend on the organised marketing of fibre at the premium end of the fine-micron fibre market. A fibre-marketing organisation and objective grading are being developed.

Economics of production

The current economics of Alpaca farming are based on returns from sale of breeding stock to other breeders. To judge by average reproductive rates, it is reasonable to assume that the speculative phase of the Australian alpaca industry will persist for the immediate future. Budgets for commercial alpaca production must obviously use broad estimates (guesstimates) since there are as yet no commercial producers.

Average world prices for alpaca fibre range from $7.00/kg–$12.00/kg greasy at the farm gate, depending on quality. In the domestic handicraft market, returns average $60.00 per kg greasy at the farm gate.

Income	Budget 1		Budget 2	
Fibre	41 kg @ $64.14/kg	$2,598	3,059 kg @ $17.82/kg	$54,513
Livestock sales	9 @ $6,778/head	$61,000	337 @ $338/head	$130,920
Total income		**$63,598**		**$150,135**
Expenses				
Shearing	$357		$8,945	
Veterinary	$30		$1,294	
Sire purchases	$0		$13,200	
Service fees	$12,000		$0	
Feed	$329		$16,558	
Interest on breeding stock capital	$18,000		$32,340	
Insurance	$10,320		$4,936	
Freight	$450		$16,850	
Other	$4		$503	
Total		**$41,490**		**$94,626**
Gross margin		**$22,108**		**$90,007**

The above sample gross-margin budgets relate to: (1) a flock of 12 breeding females on 2.5 hectares in the current speculative environment and (2) a flock of 400 breeding females on 300 hectares in a future commercial industry. Budget 1 is based on current market price for livestock, handicraft prices for fibre, current fleece production averages and a weaning rate of 75%.

Budget 2 is itself speculative. It assumes livestock prices of 5% of current values, prices for fibre are discounted by approximately 75%, 50% increased average fleece production per animal, a 30% reduction in shearing costs and a weaning rate of 85%. Returns in both budgets show figures that are averaged across all ages and classes of stock.

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Key references

Tuckwell, C.D. 1994 *The Peruvian Alpaca Industry* Rural Industries Research and Development Corporation

Australian Alpaca Conference: Proceedings. Available from the Australian Alpaca Association

Calle, Escobar R. 1984 *Animal Breeding and Production of American Camelids* Talleres Graficos de ABRIL Press, Lima, Peru.

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Cashmere

Bruce McGregor

Introduction

Australian production of cashmere is valued at approximately $0.5 million per annum. Cashmere-producing goats also benefit pasture, help to control many weeds, and produce premium goat meat.

Australian-grown cashmere has been sold on international markets since 1982. Like the mohair industry, the cashmere industry has established marketing and processing infrastructure. To increase exports of cashmere, more farmers and more farmed goats are needed. Cashmere production could increase in most areas and the challenge is to get goats onto farms.

Readers are referred to the chapter on mohair for advice on weed control using goats, pasture management and for general husbandry matters. This chapter contains additional information relevant only to the cashmere industry.

Cashmere is the premier soft-handling, luxury fibre. Demand usually far exceeds the current world production of about 4500 t, of which 2500 t come from China and 1150 t from Mongolia. While cashmere prices do fluctuate with fashion changes, they rose faster than inflation between the 1950s and 1989, while the real prices of wool have fallen relative to inflation.

The Australian cashmere industry has received orders from Europe and from China for 1000 t of cashmere annually, but currently produces only about 20 t. The cashmere industry is well organised, has one industry-owned marketing structure, has excellent contacts with overseas processors, and has had excellent scientific and technological research to direct its development. The main constraint is that there are too few animals on the farm producing too little cashmere per head.

Fleeces from cashmere goats contain coarse hair, which has no commercial value, and a fine soft undercoat, or down. It is this fine down which is called cashmere. A small number of goats grow down which is not suitable for sale as cashmere and these goats are culled for meat production.

Markets and marketing issues

Australian cashmere is sold via a tender system based on objective measurements of the fibre. The selling system is operated by the industry-owned Australian Cashmere Marketing Corporation. Most cashmere is exported in the raw state to Europe, USA

and China where initial processing is done. The dehaired cashmere may then be spun and made into fabrics in other locations. Several Australian manufacturers have purchased fibre and produced knitwear for local consumption and export.

About the author

Bruce McGregor is a Senior Animal Scientist. Since 1977 his extensive research and advisory programs have developed scientifically based practical management recommendations for mohair, cashmere and goatmeat production in non-tropical regions of Australia.

Major markets for finished cashmere textiles are Europe, Japan and the USA. China is rapidly developing its cashmere manufacturing sector and is now the main exporter of cashmere textiles. As a consequence, less raw cashmere is being traded. This trend will accelerate and increase demand for Australian cashmere.

Prices of cashmere are related to mean fibre diameter and fibre colour. In 1996 white cashmere < 16 µm brought \$90/kg clean cashmere down, coarser white and lightly coloured cashmere realised \$70 to \$80/kg clean down and brown and grey cashmere sold for \$55/kg down.

Production requirements

See chapter on mohair. As cashmere goats generally have much shorter fleeces than mohair-producing goats they are less likely to become entangled in scrub during weed-control programs. This allows them to be used longer for that purpose.

Breeds

Cashmere is produced by commercially farmed 'Australian cashmeres' and by feral goats. It is possible to purchase feral goats (50 to 80 g cashmere per year) and domesticate them but it is now far easier to purchase domesticated and more productive 'bred-on' cashmeres (120 to 200 g cashmere per year). Established breeders now have fifth-generation selected cashmeres for sale with production as high as 300 g cashmere per year.

It is best to plan your purchases in advance by arranging to buy goats from established breeders. Currently many potential fibre-producing and breeding goats are slaughtered for meat. Goats are not usually sold in sheep and cattle markets. Specific goat auctions are held at major shows.

Key messages

- International markets want more product
- Selling products through marketing system for 15 years
- Large benefits in weed control
- Established small industry with informed association
- Excellent technical information available

Yearling bucks growing cashmere at a leading Australian stud.

Table 1. Gross margin returns (GM) from cashmere (Davies and Murray 1997)

Enterprise	GM per head	GM per DSE [a]	GM per $100 of livestock capital
Cashmere (8 years of selection)	$26.77	$11.79	$103
Cashmere (feral flock in 2nd year)	$16.50	$ 7.27	$ 64

[a] DSE = dry sheep equivalent, the feed required for a 45 kg Merino wether.

Key statistics

Products	1995/96 Value $ million	
	Production	Exports
Cashmere	0.5	0.5[a]

[a] Some cashmere is locally consumed and some of the exports are processed.

Animal husbandry and disease control

See chapter on mohair.

Harvesting, handling and marketing requirements

Cashmere goats are shorn once a year in midwinter. Delays in shearing will result in the valuable cashmere down being moulted by the goats and lost or cotted, with a resultant loss of income. During shearing, contamination of white fibre with coloured fibre must be avoided. Shed hygiene standards should be followed. See also chapter on mohair.

Economics of production

Stud goats may cost from $250 per head but commercial-fibre goats can be purchased from about $25 per head. If fencing is required capital inputs will be greater, and this is best undertaken when fencing on a property is already run down. Returns on capital vary from about 0% when significant capital is required to about 40% per annum when benefits arise from weed control.

Key contacts

Industry Association:
Australia Cashmere Growers Association Ltd
30 Cann Street
Guildford, NSW 2161
Phone: (02) 9632 7476
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Email: cashmere@acga.asn.au

In each State the farmer associations have goat industry sections that can provide industry development contacts and information, consult your telephone directory.

Key references additional to those in chapter on mohair

Browne, R. J. (Ed.) 1990 *Cashmere Goats Notes* 2nd Edition, Australian Cashmere Growers Association, Guildford, NSW, 350 pp.

Davies, L. and Murray, G. 1997 *The Economics of a Commercial Cashmere Goat Enterprise* Rural Industries Research and Development Corporation, Canberra.

Industry Journals

- *The Australian Goat Report* published fortnightly and The Goat Farmer magazine, phone 045 761 218.
- *Cashmere Australia* published by Australian Cashmere Growers Association Ltd.

The crocodile industry

Steve Peucker

Introduction

Commercial crocodile farming began in Australia in the 1980s. The industry currently comprises eighteen farms situated in Queensland, the Northern Territory and Western Australia. The main products are skins and meat. High quality handbags, boots, belts, briefcases, and luggage are manufactured from the skins. The Australian saltwater crocodile is reputed to produce the finest quality skin of all crocodilians.

Crocodile farming is capital-intensive, long-term and export-orientated. Opportunities exist for market expansion in Asian and Pacific rim countries. The Australian industry is small in terms of world trade and currently supplies about one per cent of the world market. Domestic demand for meat currently exceeds production and the trend for quality leather products is steadily increasing. Production is forecast to more than double in the next five years. Value adding is occurring in Australia through joint venture partnerships with producers and foreign investors.

The small size of the industry, poor availability of breeding stock and the lack of ranching (in Queensland) are seen as limiting the industry's rate of expansion. Vertical integration, using contract growers, offers the industry one avenue for increasing industry numbers.

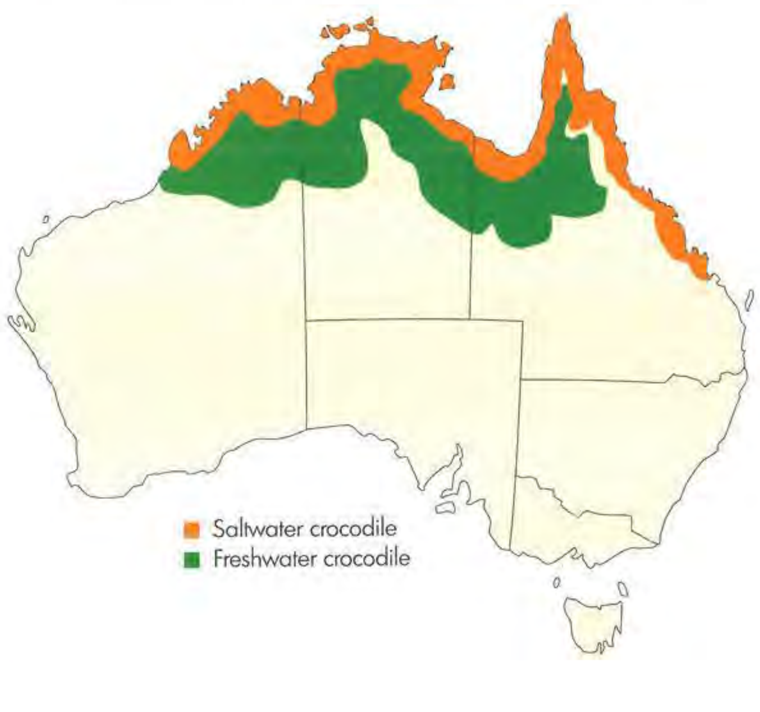
Zimbabwe, Papua New Guinea and Indonesia are Australia's major competitors. Crocodile farming is as demanding as any other agricultural industry, requiring hard work and an eye for marketing opportunities.

Markets and marketing issues

The principal markets for Australian saltwater crocodile skins are Japan, France and to a lesser extent Singapore and Italy. Australia primarily exports raw or 'green' skins for the purposes of processing and manufacturing into high-quality leather goods. 'Classic' skins as they are known, are traded in two forms, belly skin and horn-back.

Prices are determined by belly width and the amount of damage to this area. Prices for a 34 cm belly are approximately $AU355 for 1st grade, 2nd grade $266 and $177 for 3rd grade. The export trade is influenced by overseas fashion trends, the Australian dollar exchange rate, market supply and value adding.

The supply of crocodile meat is dictated by the demand for skins and for this reason processing of the meat can be irregular.



Crocodile meat is mainly consumed on the domestic market, principally through restaurants, specialty meat outlets and some large national foodchain stores. Meat retails for between $22 and $27/kg. Demand for crocodile meat exceeds production to the extent that Australia imports meat from Papua New Guinea. Export markets exist in Great Britain, Denmark, Switzerland, China, Japan, Korea and New Zealand.

Some of the issues facing the crocodile meat industry include a lack of knowledge by consumers and trade personnel about quality, the nutritional value of the meat and where meat can be purchased. Under current laws meat can only be sold frozen, while market research shows there is a strong demand for chilled crocodile meat. There is also a belief among some consumers and the retail industry that trade in crocodile meat is illegal.

Production requirements

Crocodile farming in Australia is situated in the warmer sub-tropical/tropical regions from Rockhampton in Queensland through the Northern Territory and down to Fremantle in Western Australia. It is possible to rear crocodiles to harvest size under controlled environmental conditions almost anywhere in Australia.

A reliable supply of good quality water either naturally or artificially heated to between 30°C and 32°C is required. Land area requirements are not excessive as crocodile production is intensive farming. For the construction of earth ponds, an impervious base of clay is needed to prevent seepage. Construction of pens in flood-prone areas should be avoided.

About the author

Steve Peucker, is an experimentalist, with the Department of Primary Industries in Townsville. He is involved in overseeing the day-to-day running of crocodile research facilities, assisting in research work and providing an extension service to farmers.

Saltwater crocodile production (1996)

State	No. of *C. porosus* on farms	No. of skins produced	Kilograms of meat produced
Queensland	19,972	3,894	16,000 kg
Northern Territory	35,665	6,410	35,410 kg
Western Australia	4,333	610	710 kg

Saltwater crocodile export and imports (1996)

No. of raw saltwater skins export in 1996	Kilograms of meat imported into Australia
15,046	87,100 kg

Freshwater crocodile production (1996)

State	No. of *C. johnstoni* on farms	No. of skins produced
Queensland	700	200
Northern Territory	1,130	505
Western Australia	1,529	4

Species

There are two species of crocodiles found in Australia, the saltwater or estuarine crocodile *(Crocodylus porosus)* and freshwater or Johnstone River crocodile *(Crocodylus johnstoni)*. Male 'salties' can grow up to 6 metres in length, while females grow to around 3 metres.

Breeding takes place in the wet season, from late October to the end of May or early June. Under farm conditions females mature at 8–10 years, males at 10–12 years. Nest sizes for mature females range from 30 to 60 eggs per nest. Breeding stock can be taken under permit from the wild, taken as 'problem' crocodiles or purchased from established farms.

Saltwater crocodile on the skinning table

The freshwater crocodile is smaller than the saltie and has a narrower snout. The males grow up to 3 metres in length. Nests are constructed in the cooler time of the year with nest sizes ranging from 10 to 25 eggs. Skins are less valued, as they have osteoderms (bone deposits) in the scales, which make them difficult to manufacture and a they have a larger scale size.

Crocodile husbandry

Local council and state government requirements should be investigated and all necessary licences and permits should be obtained before starting to prepare sites and buy animals. Most states have a code of practice and animal welfare guidelines. The site should have a gentle slope with an external boundary fence and internal pen fencing consisting of steel posts and wire mesh. A suitable water effluent site should be established which is adequate to handle discharge requirements. The location of the farm is important and it should be established close to power, water, feed supplies and other services. If a captive breeding program is to be used then an incubator will be required. In addition, a separate area for food preparation, coldrooms, refrigerators, and a large meat-mincer are necessary.

There is no standard method of rearing crocodiles. Farms have developed systems that suit their own particular establishment and situation. Crocodiles are grown in a variety of pen sizes and designs. Hatchlings (1–12 months old) are generally housed indoors or in covered areas. Pen design for hatchlings range from small Besser-block pens, to tanks constructed of plastic, cement or fibreglass. Each design provides an area of water and land. Ideally, pens should drain and refill independently of one another to minimise disease transmission. Colourbond sandwich panelling provides ideal insulation for fully controlled environmental sheds. Hideboards cover part of the land and water area of the pen and offer young crocodiles an added sense of security.

Grower animals (1–3 years old) are mostly housed outdoors, relying on natural climatic conditions. Pens comprise mainly single water and land areas. Water depth is generally shallow, ranging from 150 to 300 millimetres. Sub adults and adults (4 years +) are housed in deeper, large, open ponds. Smaller colonies with one male to several females are preferred. Also a one-to-one mating system is used.

Typically hatchlings are fed diets of red meat and chicken heads, supplemented with a vitamin and mineral premix. Work is currently under way to develop a pelleted feed which will better suit the nutritional needs of animals. Grower animals are also fed poultry and red-meat based diets. Adults are fed poultry (defeathered), fish, pig and beef.

Key messages

- Ensure your source of hatchlings
- Secure market outlets
- Crocodiles take three years to harvest
- Protect skin quality

Flaying a saltwater crocodile skin

Incubation time for saltwater crocodiles varies with incubation temperature. At the optimal temperature of 32°C, hatching occurs at about 77 days. Saltwater crocodiles are harvested at 1.5–2 metres in length by which time they are between 2 and 3 years old.

Pest and disease control

The environmental temperature in which crocodiles are housed and hygiene are two of the most important factors in preventing disease. Body temperature regulation is critical in minimising disease in crocodiles. Research shows that water temperature is more important than air temperature in maintaining and growing healthy animals.

Sick crocodiles often seek out areas of higher temperature. This action, termed 'behavioural fever' raises the body temperature of the animal which helps it to fight an infection. Disease affected animals should be segregated if possible. Generally, hatchlings within 6 months of age are most prone to diseases. Mortalities can be high in some instances. The major problems are nutritional disorders, viral, bacterial, fungal diseases and parasitic infection. Some of these diseases can damage the skin. Disease in older animals is considerably less frequent.

Managing disease outbreaks can often cause stress to the animals and exacerbate the problem. A high standard of hygiene is required, with regular cleaning of pens, equipment and feed preparation areas using a disinfectant cleaning agent. Only fresh, uncontaminated feed should be used for all animals. Some medications can be added to the water or feed.

Veterinary advice should be obtained when dealing with sick crocodiles because it is often difficult to isolate the primary cause of the disease. Treatments include antibiotics, antifungal and antibacterial drugs. Sometimes prescriptions will be needed to obtain drugs. It should be noted that the indiscriminate use of medication such as antibiotics can lead to disastrous situations. Withholding periods for some medication must be followed under new meat-testing standards.

Harvest, handling and processing

Harvesting begins with an inspection of animals for size and skin condition. The selected animals can either be caught and transferred to a holding pen or harvested immediately in the pen. The use of a holding pen reduces stress and disturbance on fellow pen-mates.

Animals should be fasted for two days before harvesting and slaughtered humanely. A .22 bullet to the top of the neck is used to destroy the brain. Then the spinal cord and main artery are severed to bleed the animal. This area is then swabbed with a sanitiser/detergent agent to prevent spoilage.

After bleeding, the whole carcass is again scrubbed with a sanitiser. Carcasses are hung by the tail overnight at 2°C, then washed and scrubbed again with a sanitising agent. Cotton balls soaked in the agent plug the cloaca to prevent any leakage from this site.

The key requirements in the skinning process are firstly, to avoid cutting or nicking the skin and secondly to avoid contact between the carcass meat and the outer surface of the skin. The carcass is placed on the skinning table with the head tied in a plastic bag to prevent contamination of the meat.

The opening lines or first cuts depend on the style of skin required. Cuts are critical in the quality of the final product, so much care is needed. Farmers are paid on belly skin width, scale pattern and the absence of cuts or abrasions to the skin. The horn-back skin is often used as a feature which displays the prominent scales behind the head and along the back. Flaying of the skin, using high pressure water, removes the remaining meat and fat from the inside of the skin. The skins are placed in the shade to drain for 30 minutes before salting.

Broome Crocodile Farm—a multifunction enterprise

After a short stint at professional crocodile hunting in the Northern Territory in the early 1960s, Malcolm Douglas returned to Darwin in 1969 to secure land for a crocodile research and display park. Crocodiles were not protected and the relevant authorities were not at all interested in utilising them. Malcolm was concerned that they were being hunted to possible extinction.

In 1978 he acquired a 2.5 hectare block of land in Broome, Western Australia, and spent five years lobbying for crocodiles to stock his development program. In 1983 he was given 11 sub-adults from an Aboriginal community. In the early 1990s Western Australia's management plan was approved and Malcolm was able to collect a small number of adult animals from the wild annually.

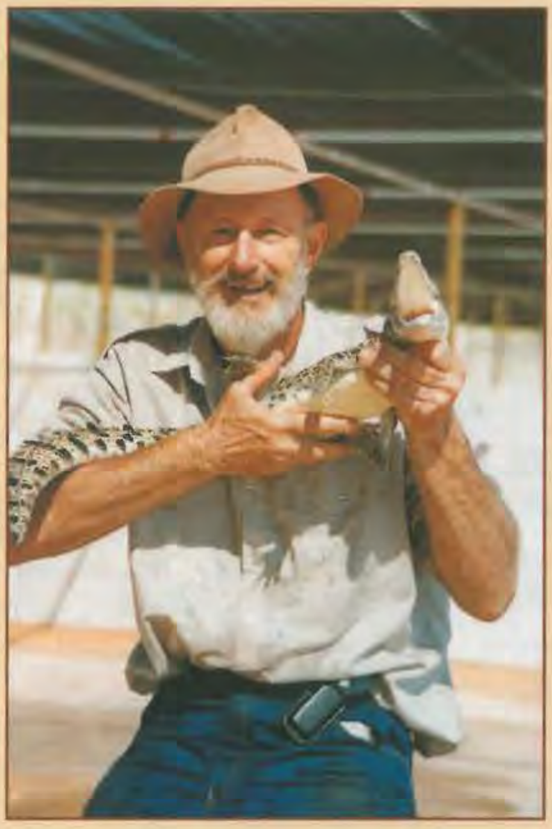
On his original 2.5 hectares, which is situated adjacent to the Cable Beach Tourist precinct in Broome, he now has over 50 breeding pairs, producing around 1500 eggs per annum.

The Cable Beach facility attracts 25,000 tourists annually. This component has been vital to supplying the cash flow for expansion.

Malcolm is currently building pens to accommodate 100 breeding pairs. The pair program allows him to monitor every male and every female. Future expansion will guarantee 3000 eggs annually, with a turnoff of 2000 skins. Malcolm is concentrating on the production of large skins and any second or third grades will be tanned and made into products at the farm.

The new farm will also incorporate a tourist facility with a museum/educational unit and a huge wetlands, utilising drainage from the ponds to attract birds. An abattoir, which is being constructed to European Union standards, will be completed by the end of 1997.

Malcolm believes that combining tourism with skin and meat sales and value adding to second and third grade skins will ensure a very healthy future for his crocodile farm in Western Australia.



Skins are salted and are dried for two days, so that excess moisture is removed. Curing the skin aids in preventing spoilage by micro-organisms. After two days the skins are rolled with the flaps (legs and flanks) tucked inside and stacked in hessian-lined wax cartons or polystyrene cartons. They are stored in a coldroom until marketed.

Under CITES regulations all skins must be tagged. These tags give details of country of origin, year of skinning and an individual number.

Economics of production and processing

Gross margin is the income derived from the sale of meat, skins and co-products less the direct costs, but not including fixed costs. In this example the fixed costs include:

- Labour $50,000
- Energy $8,500
- Permits $3,670
- Rates, Repairs & Maintenance costs

Income	
skins	$595,000
meat and co-products	$105,000
Total income	$700,000
Running Costs	
Feed	$200,000
Medication	$1,500
Processing	$46,000
Hatchlings	$105,000*
Total running costs	$352,500
Gross margin = $347,500 (N.B. does not include fixed costs)	

* based on purchasing 2100 hatchlings @$50 each

Black tanned skin and quality leather products

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Key references

Webb, G. J. W., C. Manolis and P. J. Whitehead (eds.) 1987 *Wildlife Management : Crocodiles and Alligators* Surrey Beatty & Sons in association with the Conservation Commission of the Northern Territory.

Proceedings from the Intensive Tropical Animal Production Seminar 1989 & 1991. Townsville Qld.

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Dairy goats and goat milk products

Bruce McGregor

Introduction

The production of goat-milk products in Australia is valued at approximately $1 million/year. The small dairy-goat industry has traditionally supplied fresh milk for health purposes.

In recent years, demand for speciality cheese production has allowed the industry to more than double in size; but the present demand for goat milk for processing far exceeds supply and so the potential for manufacturers to grow is constrained. The biggest limitation for the industry is the lack of commercially orientated dairy-goat farmers. Processors currently supply markets in Australia and overseas. While quality livestock are limited to some extent, dairy goats have been exported to Asian countries.

As with all dairy industries, producers must be highly committed to meet the daily demands for milking. A number of producers are vertically integrated up to manufacturing stages. A vast amount of information on dairy goat production is available from overseas.

Markets and marketing issues

Fresh goat milk receives from $0.60 to $0.80/L from speciality cheese and yoghurt manufacturers. Location near a manufacturer is preferred. Some businesses produce milk, manufacture goods and distribute the products to capital city markets. Some products are targeted to specific ethnic markets while others are designed for specific menus at cordon bleu restaurants and speciality food businesses. Export demand exists for goat-milk products in Europe and the USA.

Production requirements

General requirements and features of goats are discussed in detail in the chapter on mohair.

Dairy goats need improved pastures in reliable rainfall districts.

Breeds

The breeds of dairy goats are the three Swiss breeds (Saanen, British Alpine, Toggenburg), their crosses and crosses of these breeds with Anglo-Nubians. It is best to plan your purchases and

make arrangements in advance with breeders as potential breeding goats which are surplus to breeders' requirements will be slaughtered for meat.

Animal husbandry

See chapter on mohair for general husbandry for goats. Dairy goat farmers need a thorough knowledge of lactation, nutritional management and the methods for the control and prevention of diseases which affect milk production. Intending dairy-goat farmers should consider completing a dairy-cow apprenticeship. Knowledge of efficient pasture husbandry, fertiliser practices and grazing management will lead to increased productivity. Improved pasture is essential for dairy-goat production.

To maximise lactation and to reduce seasonal reductions in milk supply, it is likely that dairy goats will need supplementary feeding. Specialised equipment for milking goats includes disbudding equipment, tattoo pliers, milking, storage and transport equipment. Goats are usually mated in autumn when their fertility is at its highest but with dairy goats variations to the mating month are required to ensure a more continuous supply of milk. Dairy goat kids are hand-raised in sheds.

Farm layout, including the siting of the shed and laneways and provision for effective rotational grazing, is essential for efficient farm and labour management. Holding yards adjacent to the milking shed need to be covered and can be used as a feed pad during wet periods.

Disease control

The important disease control issues are discussed in the chapter on mohair. In order to ensure that dairy products meet food safety standards the withholding periods for all chemicals used in the control of diseases must be strictly adhered to. The withholding periods will be stated on the package in which the chemicals are sold.

Efforts are being made to eliminate Johnes Disease and CAE (Caprine retrovirus) from dairy goats. Potential purchasers of goats should avoid purchasing goats exposed to these diseases.

Dairy goat kids are hand raised for replacements or for capretto.

About the author

Bruce McGregor is a Senior Animal Scientist whose extensive research and advisory programs in the Australian goat industries have developed scientifically based practical management and nutrition recommendations for non-tropical regions of Australia.

Harvesting, handling and marketing requirements

Dairy goats are milked with modern milking machinery designed and adjusted for goats. Specific modifications relate to the teat size, operating vacuum, and pulsating settings. Efficient milking shed designs are available with design principles being very similar to modern cow dairies. Milking-shed practice and hygiene must be at the highest level to avoid contamination. Detailed technical information is available. Milk must be stored under refrigeration once it has been harvested and prompt processing is essential. Dairy goats are usually milked twice daily and supplementary feeding of energy supplements is common at milking. Proximity to a manufacturing works will facilitate regular milk collections and reduce transport costs. Testing the quality of goat milk will ensure that standards are met and provide information to improve production practices.

Typical lactations last for 300 days and herd averages range from 2 to 3 L/doe/day. At the peak of lactation, average production may reach 3.5 to 4 L/doe/day. The average herd produces about 700 L/doe/lactation.

Meat production. Dairy goats, particularly culled male kids, are commonly sold for meat production. The chapter on goat meat gives details of meat production requirement, markets and production issues.

Economics of production

Information on large-scale economic production of dairy goats in Australia is not available. Data are taken from a new development project in Victoria with two expanding dairy-goat farms. These farms were producing about 3800 L/ha and the gross margin was $0.34 to 0.46/L. The economic return depends on the scale of operation with about 250 does being recommended.

Many dairy-goat farmers have had to start with lower numbers and build up their herds and their experience. However, in the early stages relatively small quantities of milk may not be marketable and so proximity to existing manufacturers and high quality standards would be advised. It is possible to run dairy-goat enterprises intensively without grazing, incurring feed costs of about $1/doe/day.

Gross margin data for capretto production is given in the chapter on goat meat.

Key statistics

Products	1995/96 Value $ million	
	Production	Exports
Dairy goat products	1.0	0.1

Key messages

- Established small industry with commercial markets
- Domestic markets want more product
- International markets want more product
- Large knowledge base available from overseas
- Requires skilled management

Key contacts

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NT, Mrs. D. Cross
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Qld, Dairy Goat Society
c/- Tom Byrne
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SA, Dairy Goat Society
c/- Miss L. Schmidt
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Tas, Ms. Lorraine Mance
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Vic, Herd Improvement & Producers Association
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Phone: (03) 9718 2041

WA, Dairy Goat Society
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Contact your local Department of Agriculture dairy specialist, dairy discussion group or dairy consultant for local information.

Key references

Proceedings of Dairy Goat Producers Seminars, 1989, 1990, 1991, 1992. Contact Ms. G. Abud, (03) 9718 2041.

Brydon, D. (Ed.) 1990 *Goat Health and Production* Proceeding No. 134 Post-Graduate Committee in Veterinary Science, University of Sydney, 500 pp.

The Goat Manual 1990, NSW Department of Agriculture, Sydney.

Industry Journals:
The Australian Goat Report published fortnightly and *The Goat Farmer* magazine, phone: (045) 761 218.

Deer farming

Bruce Mackay

Introduction

Although the farming of deer is relatively new in Australia, deer have been farmed commercially in other countries for hundreds of years and there is evidence of deer-farming in China for over 1000 years.

The deer industry was established in Australia in the early 1970s when interest in the farming of deer spread here from New Zealand and its commercial value was recognised. Since then the industry has experienced the fluctuations in prices and interest common to emerging industries and ranging from the initial boom period, when new investors paid high prices for a unique and scarce live animal, to the inevitable crash when the live animal market gave way to a product-based market and prices stabilised as that market became established.

Deer farmers have three potential sources of income:

a) sale of slaughter stock for venison

b) sale of velvet antler and other by-products

c) sale of breeding stock, which in recent years has included export of live deer.

Venison, the meat produced by deer, is a very lean meat. It also tends to be low in saturated fats and relatively high in essential fatty acids, making it a healthy product. Venison is often promoted as 'the healthy alternative' and it has good prospects for sales in the health food market.

Velvet antler is the complete antler harvested from male deer at a precise stage when it is soft and vascular before it calcifies and hardens. All male deer grow and shed their antlers in an annual cycle. While not all species of deer farmed in Australia are used for velveting purposes, all deer must have their antlers removed to ensure safety and ease of management.

Velvet antler is a highly prized substance in the practice of oriental medicine and it is also being increasingly used in western communities. Recent research by Professor Peter Ghosh at Royal North Shore Hospital has demonstrated the value of powdered deer velvet to ameliorate adjuvant and rheumatoid arthritis. Further research on this is now being undertaken.

Low labour requirements and the natural beauty of deer make them an attractive proposition for first time farmers as well as for traditional farmers to diversify into a new livestock industry.

Nutritional value of venison

Product	Fat (g/100 g)	Cholesterol (mg/100 g)	Protein%	Calories/100 g	Kilojoules/100 g
Venison loin, cooked	3.0	66	25.8	132	554
Venison leg, cooked	6.0	73	33.8	190	798
Beef lean, cooked	7.4	87	28.0	182	765
Lamb lean, cooked	8.0	112	28.2	190	798
Veal lean, cooked	3.0	110	31.0	159	635
Chicken roast (no skin)	8.0	90	28.1	192	807
Chicken roast (skin and meat)	14.0	154	23.0	224	942

Key statistics

Deer numbers in Australia

Year	Number
1989/90	59014[a]
1990/91	77386[a]
1991/92	98039[a]
1992/93	125931[a]
1993/94	148811[a]
1994/95	144281[a]
1995/96	Not available
1996/97	Est. 160,000

[a] Australian Bureau of Statistics

Markets and marketing issues

There are domestic and export markets for venison and export offers the best returns. Over 80% of Australian-produced venison is now exported, mostly to Asia.

The major world market for venison has traditionally been Germany where it is prized as game meat. Around 40–50,000 t of venison are consumed in Germany annually including about 5,000 t from New Zealand.

Other major markets for farmed venison lie in the European Union, Scandinavia, Switzerland and the USA. These tend to be traditional 'game' meat markets where consumers gladly accept meats such as venison. They are large markets with limited Australian market penetration because of the current small size of our industry and our inability to provide the volume required. Several Australian venison processors are now developing these European markets and this trade is expected to go on expanding.

Exports of Australian product have been aimed principally at Pacific rim countries. These are difficult, non-traditional venison markets but the low-volume orders can be readily met by Australian suppliers. Australian venison is now selling successfully, particularly in Korea and Malaysia, with a large proportion of product meeting Halal kill-specifications. Most export product comes from NSW which, unlike other states, has export-accredited slaughter facilities for deer.

Australia's major competitor on the world market is New Zealand which farms around 1.2 million deer. Other countries have small but developing deer industries and are not likely to pose any major threat in the short to medium term

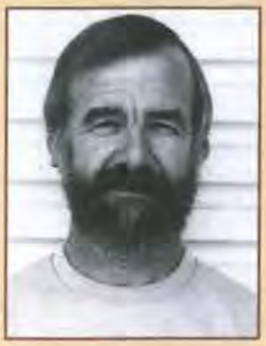
Venison animals are slaughtered at 15 to 24 months of age with carcase weights ranging from 28 kg for fallow up to 55 kg for red deer and higher for wapiti hybrids. Slaughter for human consumption must take place at registered abattoirs where the animals undergo normal rigorous meat-inspection procedures.

Venison production in Australia

Period	Number slaughtered	Hot carcase weight
1 July '92–30 June '93	12,000	396,000
1 July '93–30 June '94	25,000	825,000
1 July '94–30 June '95	30,000	985,000
1 July '95–30 June '96	34,000	1,040,000
1 July '96–30 June '97	21,000	635,000

Source: RIRDC

About the author



Bruce Mackay is an honours graduate from Hawkesbury Agricultural College and is employed by NSW Agriculture as a District Livestock Officer. He has been located at Orange in the central west of NSW as District Beef Cattle Adviser since 1972.

Bruce's interest in deer is a personal one and dates back to 1976 when he attended a very early deer industry day conducted at Orange. He maintained an interest in the industry until 1983 when he was officially appointed as the Department's officer responsible for deer farming across NSW. Since that time he has worked closely with the industry and was appointed a life member of the NSW Deer Farmers' Association in recognition of his services in 1991. He has written numerous articles on deer farming and has studied the deer industries in New Zealand and China. See *Key contacts* for address.

Yearling red deer (spikers) in central NSW

An estimated 20,000 head will be slaughtered nationally for the year ended 30 June 1997 compared to 34,000 in 1996 and 30,000 in 1995, which highlights the concern that there are not enough deer in Australia to meet market demands. Returns to producers for venison have varied markedly in recent years, but carcases meeting optimum specifications have been returning up to $2.70/kg live weight or more.

Velvet is frozen on farm after harvest and is sold either through the industry-run velvet pools or direct to Asian buyers. Traditionally, the velvet market has been volatile but in recent years prices have been relatively stable at around $120/kg for top grades. Good quality mature red stags can yield up to 3 kg or more.

Most Australian-produced velvet is processed and used locally, but the major world markets for velvet are China, Korea, Hong Kong, Taiwan and Singapore.

Other products from the deer industry include skins, tails, pizzles, sinews, and blood.

Although there is a market for these products, its development is restricted by the small volume of supply.

Production requirements

Deer are very adaptable and, with careful selection of species, can be run in most parts of Australia. However, they are mainly being farmed on better-quality grazing since they thrive on good quality pasture. Access to irrigation is an advantage, particularly to ensure that adequate turn-off weights are achieved. Most pasture species considered adequate for sheep and cattle are suitable for deer. Steep country that is difficult to fence and muster and country traversed by water courses should be avoided. It is also important to provide shade in summer and protection in winter, particularly for fawns. Access to slaughter facilities and markets can also be an important consideration in locating a deer farm.

Red deer stag in South Australia

Stocking rates for deer will depend on the quality of the country and will vary with the time of year, but as a guide one beef-breeding cow is equivalent to four red deer or eight fallow deer.

Deer generally require specialised fencing and handling facilities as they are very agile and can readily jump 2 m or higher. Some States have specific requirements for boundary fencing which can be up to 2.1 m high but where no regulations are in force, boundary fences should be high enough to prevent the escape of deer and of the best affordable quality. A range of materials is available for deer fences including specially constructed deer-netting in various specifications.

Farm layout and design are important to the workability of a deer farm and the ease of stock management. The most practical way to move deer is along laneways. Ideally, all paddocks will be connected to a laneway system that allows ready movement of deer from paddock to paddock and to the handling yards.

The main working area of deer yards is generally under cover as deer are easier to handle in subdued lighting. Yards need not be elaborate but do need to allow for such practices as drafting, vaccination, weighing, de-antlering and loading. Commercial crushes are readily available that assist with the handling of deer.

Breeds of deer

There are many species of deer in Australia but not all of them are suited to large-scale farming. Six species that can be classified into tropical and temperate species are farmed commercially.

Tropical species:

Rusa – *Cervus timorensis russa* (Javan), *Cervus timorensis moluccensis* (Moluccan)

Chital – *Axis axis*

Temperate species:

Fallow – *Dama dama dama* (European) and *Dama dama mesopotamica* (Mesopotamian)

Red – *Cervus elaphus*

Wapiti – *Cervus canadensis*

Sambar – *Cervus unicolor*

The choice of which species to farm will generally depend on climate, personal preference and market for products, but availability and price also needs to be taken into account. The number of farmed deer in Australia is estimated at 160,000 head, comprising 40% Red deer, 50% Fallow and 10% other species. Red deer, which have heavier carcase weights, are estimated to make up closer to 60% of venison production. Red deer have shown the greatest increase in numbers in recent years thanks to their versatility, production potential and suitability for farming.

Key messages

- Deer farming is now a well established industry in Australasia
- Deer farming is a product-focused industry
- There are well-established international markets for all deer products
- Markets for deer products exceed supply
- Deer farming offers diversification opportunities for existing farmers as well as new farmers

The temperate species are of European origin and adapt readily to the Australian climate. They have a well-defined breeding season with the mating season generally beginning in early April and lasting around four to six weeks. Fawns are born largely in December and January.

Tropical species are less seasonal in their breeding habits and are more suited to the warmer parts of Australia

Some hybrids are now being used commercially to gain production advantages from hybrid vigour (heterosis) and additive genetic effects. The main crosses being used are European ¥ Mesopotamian Fallow and Red ¥ Wapiti. While Sambar and Rusa will cross-breed, commercial use of this hybrid is limited. Other species do not naturally hybridise.

Terminology used for the sexes of different species of deer

Species	Male	Female	Young
Red deer	Stag	Hind	Calf
Wapiti	Bull	Cow	Calf
Rusa	Stag	Hind	Calf
Chital	Stag	Hind	Calf
Sambar	Stag	Hind	Calf
Fallow	Buck	Doe	Fawn

Deer husbandry

Farm-bred deer can be readily handled but cannot be regarded as fully domesticated and basic stock handling skills are a prerequisite. Deer are very intelligent and are generally predictable in their behaviour. They are easy to train and education at a young age to accustom them to being mustered and yarded pays dividends. However, the deer farmer needs plenty of patience, to be a good observer and have an understanding of animal psychology. Regular supplementary feeding can be a useful aid to keeping deer quiet and easily handled. Deer can be readily worked with dogs but it is essential that they are not rushed or crowded but allowed plenty of time to find gateways and to move up the laneways into the yards.

While the temperate species have a distinct seasonal breeding pattern, controlled joining greatly assists in the management of the tropical species. The mating season of the temperate species (called the rut) generally begins in late March and females are normally left with the males for a period of 8 weeks. Males can become quite aggressive during the rut and it is advisable not to handle deer at this time.

The first fawns are produced in late November and if males are removed after 8 weeks, fawning will be completed by late January. Both males and females can be bred at 16 months of age with females known to breed until they are at least 16 years old.

During the mating period, males eat very little and depend on body reserves for survival. Following the rut and for the remainder of the winter, feed intake remains virtually at maintenance levels even with high-quality diets and abundant pasture. This means that pre-rut feeding management of breeding males is of critical importance to ensure that males are able to survive the winter. This feed intake pattern is also evident in females but to a far lesser extent.

Nutrition of lactating females is also important as often summer feed may be of poor quality and may need supplementing.

Castration is not widely practised in the deer industry, mainly because of the lower weight gains of castrates. However, there are some marketing advantages in castrates: they can be slaughtered all year round; the problem of aggression is overcome; and meat quality does not change because of the rut.

Australia now farms over 200,000 deer

Deer weights and sizes

Species	Males		Females		Birth weight
	Weight (kg)	Shoulder height (cm)	Weight (kg)	Shoulder height (cm)	Weight (kg)
Red	180–300	130	90–120	90	8–9
Wapiti	350–450	150	230–250	125	9–11
Rusa					
Javan	120–160	100–110	70–85	90	4–5
Moluccan	80–100	95	50–60	85	4–5
Fallow	75–100	90	42–50	76	4.5
Sambar	180–300	127	150–200	115	5–6
Chital	70–90	90	40–50	80	3.5

Red deer and good pastures—a good recipe for profit

Velvet antler production is a specialised operation requiring good husbandry and a knowledge of animal physiology, genetics and nutrition along with an appreciation of harvesting skills and post- harvest care. Generally the best markets are for velvet from red, wapiti and their hybrids, although markets do exist for velvet from other species. Timing of velvet harvest is critical to maximise velvet yield and to ensure that velvet is of high quality. Velvet can only be removed by qualified veterinarians or farmers who have undergone specialised training and are accredited to velvet their own deer.

Pest and disease control

Deer are very hardy animals and relatively free of pest and disease problems. Most problems associated with deer are the result of stress, either nutritional, climatic or from handling and well managed deer suffer from very few health problems. However it is recommended that they be vaccinated against clostridial diseases annually.

Processing

The processing of deer at abattoirs and the subsequent boning and packing of venison are generally restricted to general abattoirs designed for slaughter of other species. While this operates reasonably well with only minor modifications required, many abattoirs remain reluctant to take on the slaughter of deer. This is due partly to the relatively small numbers and intermittent supply of deer available for slaughter and the sensitivity of export abattoirs to any situation that could jeopardise their export consideration, At least one specialist deer-processing plant with export accreditation will commence production in 1997 which will further improve market access.

Velvet processing plants have been established in NSW and Western Australia. The pharmaceutical standard velvet processing plant at Goulburn in NSW has been in operation for a number of years producing a range of deer-based products which are sold commercially across Australia. Velvet processing generally involves cooking at high temperatures, often in a steam bath, then drying to remove moisture. This product can then be sold in sliced or powdered form in capsules. The active ingredient of velvet, called Pantocrin, can also be extracted for use in tonics.

Economics of production

Anyone considering entering the deer industry should look carefully at the economics of the industry and develop their own budgets without reliance on any one source of information. Gross margins are a first step in making comparisons between industries but they are not a measure of profitability—they merely show the difference between the gross income earned by the enterprise and the variable costs associated with it. They do not consider overheads.

Capital costs for land and for setting up a deer enterprise will vary widely with location and the scale of the operation. The following costs can be used as a guide:

Capital costs	
Fencing – new	up to $5/m
– grade	from $2/m
Yards	from $10,000 up
Trailer and crate	approx. $3,000
Livestock costs	
Red hinds	up to $350
Red stags	$500-$5000
Fallow does	up to $100
Fallow bucks	up $150 or more
Other species	depends on
all prices vary with	location &
age and quality	availability

Gross margins based on returns for venison of $4.00/kg carcase weight ($2.20/kg live weight) are:

Enterprise	Stocking rate	Gross margin	Gross margin per hind/doe	Gross margin per DSE
Herd of 50 Red deer hinds	8 DSE*/ha (2.6 hinds/ha)	$6,797	$136	$45
Herd of 500 Red deer hinds	8 DSE/ha	$94,732	$189	$67
Herd of 100 Fallow does	8 DSE/ha (5.2 does/ha)	$7,293	$72	$49
Herd of 500 Fallow does	8 DSE/ha	$37,929	$75	$53

* DSE = dry sheep equivalents

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Australian Venison Processors Association
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Key references

Australian Deer Farming Manual
produced by and available from Red Deer Society of Australia

Deer Farming in NSW
A manual compiled by and available from Bruce Mackay, NSW Agriculture

Australian Deer Farming Magazine
Available on subscription from A. Cowan, Maroondah Highway, Buxton Vic. 3711

Most Deer Industry Association of Australia State branches also have available a range of reference material.

Rockley Deer Park—integrating production and processing

In 1989, Sydney businessman Rod Maclure acquired a sheep-grazing property at Rockley in the central highlands of New South Wales and proceeded to develop a commercial red deer farming enterprise. At that time in Australia it was difficult to obtain lines of quality red deer at reasonable prices, so it was decided to import the initial breeding stock of 135 hinds and a few excellent stags from New Zealand.

The development of the deer farm was carried out progressively to a master plan developed by the Rockley deer farm manager, Mr Russell Dawson. Russell is a New Zealander with around 25 years experience in the industry.

The master plan for the development of Rockley Deer Park has been completed, with more than 25 km of deer fencing, excellent yards and handling facilities, including a hydraulically operated crush with scales.

Within the first seven years the deer farm reached its optimum stocking rate of around 1,000 breeding hinds and 150 velveters. For short periods numbers reach up to 2,500 red deer.

The velveting herd includes some excellent sire stags and other stags which have been hand selected over the years.

The age of the herd ranges from some spikers to mature stags. The velvet yield averages more than 3.0 kg/head and over the years has produced very lucrative returns for the deer farm. However, the highest revenue has come from selling livestock and deer for slaughter to produce venison.

In the early 1990s, Rod Maclure began slaughtering deer for venison to supply the domestic market. This was mainly for the hotel/restaurant trade in Sydney. Realising the limitation of the domestic market, he recently began exporting venison to Asia and Europe. Deer were slaughtered at a large multi-species abattoirs and processed in non specialised boning rooms.

There were always problems associated with processing venison in non dedicated works and it was difficult to obtain a consistent quality product.

When the opportunity arose to purchase a small domestic abattoir at Oberon, just 30 minutes from Rockley Deer Park, Rod Maclure bought the plant with the intention of redeveloping it as a specialised deer slaughter facility with full export registration. Before commencing the project, a number of deer slaughter plants were visited in New Zealand and some of the best features from the various plants were incorporated in the plans for the Oberon deer slaughter plant and the boning room.

The deer slaughter plant has now been completed and incorporates many specialised features using state-of-the-art technology. The yards (lairage) have been built to very hygienic standards and to minimise stress and bruising. The knocking box/restrainer is pneumatically operated and is unique.

In the slaughter room the deer are electrically stimulated, using a specially designed low-voltage stimulator. This ensures that the venison is tender and does not get tough through cold shortening. The carcases are dressed using a pneumatically operated inverted dressing rig. Inverted dressing is regarded as the most hygienic method.

This project is the only one of its kind in Australia at present and represents a substantial investment in the future of the deer industry. Rod Maclure has demonstrated his confidence in the industry and hopes that the new deer slaughter premises will be the catalyst for continuing strong growth by the expansion of existing deer farmers and from the entry of new deer farmers into the industry.

Emu farming

Peter O'Malley

Introduction

Commercial emu farming to produce emu meat, leather and oil started in Western Australia in 1987 and the first slaughtering occurred in 1990. By 1994 all Australian States permitted emu farming and the industry produced an estimated 75,000 chicks in 1994 and 110,000 in 1995.

Production was curtailed in 1996 when it became clear that production was exceeding developed markets. The industry still produces too much and it is likely to shrink considerably before it grows again.

Despite this there are a number of positive signs:

- Markets are expanding and there are moves toward an 'Australian' industry focus and the development of cooperative market arrangements.
- There is still tremendous faith in emu meat, emu leather and emu oil as high quality products.
- The development of an industry quality-assurance program for products.
- Research is focused on product development and gaining Therapeutic Goods Agency registration for the unique properties of the oil.
- World interest in farming emus is increasing. The United States of America has the biggest population with estimates of up to 1.5 million birds. Europe, Canada and China have 15–20,000 birds each, New Zealand 2–3000 and farms are being established in a number of Asian countries.
- Production technology is well developed.

Meat, skin and oil are the major products from emus; carved emu eggs and small quantities of emu feathers are also sold.

Emu meat is a low-fat, low-cholesterol (less than 0.05%) meat which has a slightly 'gamey' flavour. The most valued cuts come from the thigh and the larger muscles of the drum or lower leg.

The emu body-skin is characterised by a raised area around the feather follicle which produces a distinctive patterned surface. It is a fine but strong leather. The leg skin has a distinctive scale pattern and is used in leather accessories and to highlight other leathers.

Emu fat is rendered to produce an oil which is used in cosmetics and therapeutic products. Emu oil is said to add a certain 'quality' to cosmetics and while it is claimed that it is penetrating and effective in the treatment of muscle and joint pain, research into this has only just begun.

About the author

Peter O'Malley is a Senior Research Officer employed by Agriculture Western Australia. He was primarily responsible for the establishment of the experimental emu flock at the Medina Research Centre in December 1987. He carried out the initial work to determine the artificial incubation, husbandry, brooding and feeding requirements of emus and is currently working to improve the quality and quantity of the oil and leather produced. See *Key contacts* for address.

Markets and marketing issues

While emu production problems have been solved quickly, developments in processing and marketing have not kept pace with production. Before emu farming began, there was no market for emu products. Now the industry is trying to place three products—emu meat, oil and leather—at the top end of world markets which know virtually nothing about them. Other new animal industries in Australia, such as the deer and ostrich industries, have the benefit of substantial research and market development carried out in other countries. In a global sense, these are mature, whereas the emu industry is in its infancy.

One of the attractions for people entering the emu industry was that they perceived it to be a 'farm to market enterprise' and they have been unwilling to seek the required expertise, or to involve marketing/distribution companies, which would take some of the 'margin'. While it is true that some individuals have operated very successful 'farm to market' emu enterprises, most have failed. Because of this desire to control all phases of the production and marketing chain, there was little cooperation, strong leadership did not develop, there was less marketing investment than required, market-led coordination in production was lacking, and the industry has been slow to introduce quality standards. There was no thought of long-term benefits through cooperation.

Today those attitudes are changing and in most states we have seen the development of cooperative emu-marketing groups and the move toward a national marketing approach. The essential elements of a successful emu industry are seen to be:

- Strategic marketing to grow a market that sends clear signals to producers to substantially control supply.
- Specific groups of business expertise working together to build a better industry.
- A quality assurance program in place across the industry.
- Unique product characteristics identified and registered with the Therapeutic Goods Agency.
- Cost-effective service providers
- Nationally, a base of commercial growers producing birds in response to clear market signals.

Although emu products are considered to be good, the current opinion of international buyers is that in general they do not come up to the standard of ostrich or other exotic products. Emu meat, long term, is likely to be sold at a price similar to ostrich or venison and at present farmers are receiving around $9.00/kg for the 10 kg of major carcase muscle and $4–5.00 for the remaining 2 kg of trim produced by each bird. Emu meat is generally selling well and markets are expanding.

Emu leather has proved difficult to tan and it has also been difficult to obtain good quality hides. It takes time to become established in the leather business. South Africa took up to 10 years to get ostrich leather accepted in the Japanese fashion industry. There is apparently an abundance of ostrich leather on the world market and the general opinion appears to be that emu leather is not as good, particularly in relation to the follicle, which is the main attribute of the skins. The current price of emu leather is around $50/hide salted (body and two legs) but the product is currently not selling well.

Available information suggests that less than one third of the leather being produced is being sold. Clear industry standards and the research to develop a leather of suitable quality for the garment trade are needed urgently.

Emu fat is sold in the raw, unrendered form, as crude or primary rendered oil or oil refined to the buyers' specifications. Price is dependent on the amount of processing involved. Oil price has fluctuated widely and crude rendered oil has reportedly sold from $10.00 to $50.00/L. About one half of the oil currently being produced has sold but farmers are reluctant to sell at less than $25.00/L.

Emu oil is considered to be the key to the success of the industry and much will hinge on obtaining its registration as a therapeutic agent. The initial results of research suggest that not all oils have therapeutic properties and production methods will need to be developed to produce efficacious oil consistently.

Production requirements

Emu farming is a semi-intensive livestock enterprise requiring suitable land, fencing and water for adult and growing stock, reliable power for hatching and brooding chicks, shedding for young birds, feed-mixing facilities and easy access to a wide range of feed ingredients or prepared feed. Chicks can be sold at hatch, 6–10 weeks of age or retained until they reach slaughter weight at 50–70 weeks of age.

While it has proved not to be a difficult enterprise, it does require a wide range of skills. Farmers need to become expert at intensive animal husbandry, breeder flock management, hatchery management, chick rearing and growing birds for market.

- Stock are difficult to handle, transport and move between pens.
- There is only limited information available on the birds' nutritional needs, breeding behaviour and potential disease problems.
- Strict hygiene of eggs and nesting areas is critical to prevent subsequent problems from disease in the chicks and to prevent loss of eggs from rotting.
- Special management techniques must be adopted to prevent chick losses from leg abnormalities.

Breeds

During the development phase of the industry, most States allowed a limited capture from the wild, but the farming of emus was only approved on condition that only captive-bred emus were farmed for slaughter. This was necessary to comply with the *Federal Regulation of Exports and Imports Act* which requires all products from native animals to come from animals bred in captivity or taken under an approved management program. The commercial industry is therefore based on existing captively-bred stock and all States, with the exception of Tasmania, have licensing requirements to protect wild emus.

Recently hatched emu chicks

Emu breeding stock in Western Australia

While there has been no study on possible genotypic differences between emus captured from different regions throughout Australia, wildlife agencies have accepted that no major differences exist. On farms, there has been only limited selection for desirable commercial traits and distinctive breed types have not emerged.

Husbandry

Breeding birds can be housed as individual pairs in pens or run as a free-ranging flock—2-ha paddocks running 32 breeders work well. The industry has an established Code of Practice and breeder pens are required to be at least 25 m square.

Most farms run a combination of free-range and individual breeding pens. Breeders are expected to remain productive for more than 10 years and a number of individual breeder pens will allow the reproductive performance of new stock to be assessed before they are moved on to a more extensive farming system.

The success of an emu-farming venture will be determined largely by its ability to hatch 75–80% of all eggs laid successfully and to rear chicks with a total mortality of less than 10%. Artificial incubation is recommended and, as a minimum, a separate setting and hatching machine are needed. Farmers should also consider storing eggs before incubation to limit the total number of hatches for the season. The ease of management and the reduction in rearing mortality achieved by the isolated rearing of each hatch offsets any loss in hatchability caused by storage.

With fortnightly settings, chicks can be placed in one of four separate brooder sheds with attached outside runs from day-old to 5 kg live weight. Each brooder shed is used at least twice each season and the chicks are moved to one of two larger sheds with access to free range at 7 weeks of age. One shed is used to house the first three to four hatches and the second to house the later hatches. These facilities will need to be predator-proof. At 15 kg live weight (20 weeks) the chicks can be combined and allowed to range over larger areas.

At the stocking densities being adopted by farmers, emus will be able to obtain only a small portion of their nutritional needs from pasture and natural browse. They will need a balanced ration which can be farm mixed or purchased. Good results can be achieved by feeding farm-mixed rations formulated to specifications similar to laying-stock rearing rations. Birds are slaughtered at 12–15 months of age and can be finished to maximum fatness in 8–10 weeks by feeding a low protein high energy finishing diet.

Breeding birds are fed an egg-layer type of ration fortified with additional vitamins and minerals.

Key messages

The industry has three new products—emu meat, oil and leather—to place at the top end of world markets which know virtually nothing about them.

The emu industry is expected to shrink before growing again. The positive signs on oil and cooperative emu marketing promise well for the future.

There is still tremendous faith in emu meat, leather and oil as high-quality products.

Pest and disease control

Emus appear to have a high level of resistance to most disease and most mortality is caused by poor hatchery and rearing hygiene. They are, however, susceptible to Erysipelas caused by the bacterium *Erysipelothrix insidiosa* (Ruthsiopathiae). This organism thrives in wet, dirty, anaerobic conditions and causes a generalised septicaemia in young growing birds, 7–12 months of age, following periods of stress induced by cold, wet weather and overcrowding in heavily contaminated pens. Vaccines developed for poultry have proved to be successful in preventing this disease.

While worms and body pests are not a common problem, some farms have found it necessary to treat for these.

Economics of production

Investment in any enterprise should be supported by a detailed farm plan which defines the production method, livestock numbers, buildings and equipment required, and marketing. This can then be used to develop financial budgets for expected cash flows, finance requirements, profit and loss, gross margins and return to investment.

A 50-female farm producing 780 slaughter birds each year would cost around $175,000 (excluding land) with a farm-operating cost of about $140 for each slaughter bird produced. Given that slaughter costs currently range from $65 to $85/bird, farmers must sell all three emu products at prices above those listed before any margin is generated.

Breeder standards	
Age at first egg	20 months
Egg production 1st year	17 eggs
Egg production 2nd year	25 eggs
Production period	April–October
Percentage of year's production	
Month 1	10%
Month 2	21%
Month 3	28%
Month 4	27%
Month 5	14%
Annual replacement (minimum)	5%
Mating ratio	1M:1F to 1M to 1.5F
Area	16 birds/ha
Average egg weight	600 g
Hatchability of eggs set	75%
Incubation period	55.5 days
Transfer to hatcher	day 50
Average feed consumption	
Average	650 g/bird/day
Aug–Dec	1200 g/bird/day
Jan–April	500 g/bird/day
May–July	350 g/bird/day
Year total	240 kg/bird
Grower standards	
Feed consumption/bird	
0–8 weeks	9.5 kg
8–25 weeks	57 kg
25–40 weeks	60 kg
40–65 weeks	153 kg
Live weight at	
55 weeks	38 kg
65 weeks	43 kg
Mortality	
0–8 weeks	12.5%
8–25 weeks	2%
25–slaughter	2%
Product yield and minimum pricing at 60 weeks of age.	
Meat (boneless)	12 kg @ $8.00/kg
Leather (salted)	7 ft2 @ $40.00 each
Fat	10 kg @ $7.00/kg (raw)
Leg skins	2 @ $5.00 each
Egg shells/breeder	4 @ $8.00 each

Emu meat processing

Key contacts

The Emu Farmers Federation of Australia has branches in all States. These provide a good starting point for further information on the industry.

Emu Farmers Federation of Australia
Mr B. Evans
Secretary
'Bosante'
Bundurra, NSW 2359
Phone: (02) 6725 2218
Fax: (02) 6725 2218

State Association Secretaries
Queensland, Carol Schmidt
P.O. Box 257
Murgon, Qld 4605
Phone: (07) 5464 4667

NSW, Annette Pollard
'Laceby'
Cartwright Hills
Wagga Wagga, NSW 2650
Phone/fax: (02) 6921 2459

Victoria, John Holt
Royal Agricultural Society of Victoria Ltd
Epsom Road
Ascot Vale, Vic. 3032
Phone: (03) 9281 7438
Fax: (03) 9376 2973

South Australia
Chris Dobbin
P.O. Box 987
Waikerie, SA 5330
Phone/fax: (08) 8583 2142

Tasmania
Fiona King
c/- Post Office
Margate, Tas. 7054

Western Australia,
Arthur Pederick
'Corralyn'
PO Box 57
Wagin, WA 6315
Phone: (08) 9861 1136
Fax: (08) 9861 1136

Peter O'Malley
Senior Research Officer
Agriculture WA
Locked Bag No 4
Bentley Delivery Centre,
WA 6983
Phone: (08) 9368 3577
Fax:(08) 9474 1295

Key references

An Introduction to Emu Farming, Emu Producers Association Victoria

Smetana, P. 1995 *Emu Farming—Background Information.* Department of Agriculture, Western Australia.

Producing the Chick booklet, Emu Producers Association, Victoria

Workshop on Emu Management: Removal of Impediments to a Sustainable Commercial Emu Industry Primary Tasks Pty Ltd, Carlton, Victoria

A Development Strategy for the Emu Industry May 1992, ACIL Economics and Policy, in association with McIntyre Management and Marketing

Goat meat

Bruce McGregor

Introduction

Production of goat meat in Australia is valued at approximately $20 million per annum. Goats used for meat production also benefit pasture and help to control many weeds. These benefits are discussed fully in the chapter on mohair.

Prime goat meat is traditionally regarded as lean, tender and juicy. It is sold under many names but 'capretto', the Italian name for tender, milk-fed kid, is the best known in Australia. Australia is the world's leading goat-meat exporter, with the majority of meat originating from captured feral goats. Orders for goat meat usually exceed our capacity to supply. Unfortunately these markets depend on the low cost and erratic sources of feral goats from semi-arid rangelands. Expanding potential markets in south-east Asia cannot be supplied as production of farm-reared goats is low. Unsupplied markets exist in all capital cities in Australia. The goat-meat industry needs greater supply of quality, market-specific goat meat, which means more goats on well managed farms in reliable grazing districts. Only some abattoirs slaughter goats.

Markets and marketing issues

Goat meat is exported at commodity prices to Taiwan (35% of the market), Singapore, Malaysia, South Korea, USA, the Caribbean and to high value markets in Europe. Frozen carcases comprise 77% of the meat trade, with bone-in cuts, boneless meat and live goats making up the remainder. Some markets have very specific requirements. Specified cuts have been sold to restaurants but this trade is severely limited by the shortage of quality animals. Smallgoods manufacturing depends on a supply of boneless meat, generally obtained from the slaughter of older goats. Currently, demand for this type of goat is relatively low. In past years live goats and carcases have been air-freighted to markets in the Middle East. Potential exists to develop chilled primal-cut markets in Asia but a predictable supply of high-value animals must be maintained.

Restaurants and butchers prefer young animals with carcases up to 12 kg although some wholesalers prefer heavier carcases. Religious festivals (Christmas, Easter and Ramadan) provide peak demand for quality carcases Export markets specifications range from carcases up to 12 kg, to carcases from 14 to 16 kg or over 20 kg. Prices vary with markets and season and range from $0.50 up to $5.00/kg carcase weight.

There is a need for cooperation between suppliers, wholesalers and retailers or exporters. High-value capretto markets can be further developed as seasonal markets which match the current supply situation. There are opportunities to supply specific cuts of chilled meat to the very high-value markets of the European Union.

Information packages for restaurants have been developed by the Australian Meat and Livestock Corporation. These show how chefs can prepare premium dishes from various goat-meat cuts. AUSMEAT, who are responsible for the description of export carcases, have developed in conjunction with the industry a Goat Meat Language so that purchasers can specify their requirements precisely.

Production requirements

General requirements are discussed in the chapter on mohair.

About the author

Bruce McGregor is a Senior Animal Scientist whose extensive research and advisory programs in the Australian goat industries have developed scientifically based practical management and nutrition recommendations for non-tropical regions of Australia.

Breeds

Meat is produced by all the fibre goats, dairy goats, feral goats and the improved boer goat. Boer goats, from southern Africa, are selected short-haired goats specifically bred for meat. Some boer goats also produce cashmere and cross-bred boer × cashmere goats are becoming more numerous. A range of pure and cross-bred boer goats is available.

A well grown boer goat kid, ideal for capretto

Animal husbandry

See chapter on mohair. For efficient meat production it is essential that predators be controlled before kidding.

Disease control

The major issues are covered in the chapter on mohair. To ensure that meat products comply with food safety standards, it is essential to adhere strictly to the withholding periods for all chemicals used in the control of diseases. The withholding periods will be stated on the package in which the chemicals are sold.

Harvesting, handling and marketing requirements

Market requirements can vary with seasons and between years so it is important to contact potential buyers, agents or your association in advance to ensure that you clearly understand the current market requirements. For meat markets it is essential to know which market is being targeted and plan appropriate mating and nutrition practice to suit.

For the best returns sell:

- healthy well fed clean goats

- goats which are in good body condition
- goats which are at least 3 weeks off shears but not in full fleece
- goats which are outside any withholding period (i.e. have not been vaccinated or drenched within a certain period, depending on the treatment – see instructions on the package)
- quiet animals which have been carefully handled and yarded to avoid bruising
- goats with the appropriate declaration forms correctly filled in
- goats ready on time for the livestock carrier
- the correct number of goats ready for marketing, no more and no less than has been agreed upon.

Kids being sold for high-value capretto markets have special requirements including light pink meat (these kids should not be weaned before sale) and tissue depth at the GR site of 3 to 6 mm (body condition score 2 or 3). It may be necessary to provide special nutritional management for twin-reared kids so that they reach marketable weight and condition at a suitable time. The supplementary feeding of grain to such kids or to their lactating does can improve carcase weight, fatness and condition.

As goats grow, the proportion of the live weight which can be sold as a carcase increases. The carcase represents about 37% of young light-weight kids but increases to about 48% for good condition goats weighing 35 to 45 kg. The amount of fat in the carcase of goats increases as they become heavier. Older, heavy goat can be too fat for some markets.

Economics of production

Gross margin data for capretto production with cashmere and mohair production are given in the Table 1. Quotes for adult goats sold for meat range from $0.50 per kg carcase weight to $30 per head. Meat prices can be volatile. Limited offers ranging from $30 to 40 per head for capretto kids have been reported and an indicative gross margin for such prices without fibre sales is given.

Key messages

- International markets want more product
- Domestic markets want more product
- Opportunities to develop strategic alliances
- Large benefits in weed control
- Requires skilled management

Table 1. Gross margin (GM) returns from capretto with or without mohair or cashmere production (adapted from Davies and Murray 1997)

Enterprise	GM/head	GM/DSE[a]	GM/$100 of livestock capital
Cashmere/ Capretto ($22/head)	$29.80	$19.86	$115
Mohair/ Capretto ($22/head)	$32.46	$20.29	$ 92
Capretto ($40/head, no fibre)	$35.33	$23.55	$135

[a] DSE = dry sheep equivalent, the feed required for a 45 kg Merino wether.

A range of goat carcasses: the lean types are used only for commodity trading, the premium heavy carcasses are ideal for chilled cuts.

Key statistics

Products	1995–96 value ($ million)	
	Production	Exports
Goat meat, leather	20	19

Key contacts

For information about Goat Meat Producer Associations or meat marketing:

New South Wales
Phone: (02) 9251 1700

Queensland
Phone: (075) 305 247

South Australia
Phone: (08) 8764 2075
Fax: (08) 8764 2145

Tasmania
Phone: (03) 6398 5144

Victoria
Phone: (03) 5428 2357

Western Australia
Phone: (09) 309 3225
Mobile: 018 942 048

Boer Goat Breeders' Association of Australia Ltd
Phone/fax: (06)3 556 290

Key references

Brydon, D. (Ed.) 1990 *Goat Health and Production.* Proceeding No. 134. Post-Graduate Committee in Veterinary Science, University of Sydney 500 pp.

Davies, L. and Murray, G. 1997 *The Economics of a Commercial Cashmere or Angora Goat Enterprise* Rural Industries Research and Development Corporation, Canberra.

Browne, R. J. (Ed.) 1990 *Cashmere Goats Notes* 2nd Edition, Australian Cashmere Growers Association, Guildford, NSW, 350 pp.

Marketing Prime Goat Kids 1996 NSW Agriculture, Orange, 11 pp.

Industry Journals:
For the *Australian Goat Report* published fortnightly, which contains the latest prices for goat meat, and *The Goat Farmer* magazine, phone: (045) 761 218.

Mohair

Bruce McGregor

Introduction

Australian production of mohair is valued at approximately $2 million per annum. Fibre-producing goats also benefit pasture and help to control many weeds. These large potential savings in labour and chemicals for weed control and in reclaiming land from weed infestations have hardly been tapped in most grazing areas of Australia.

Australian-grown mohair has been sold on international markets for over 25 years. During the past 10 years the mohair industry has invested heavily in obtaining the best genetics available in the world. Such animals are now available for new entrants in the mohair industry. Marketing and processing infrastructure is available. To increase exports, the industry needs more farmers with more farmed goats. Mohair production could increase in most districts and the challenge is to get goats onto farms.

Being agile, goats can be grazed on steep, inaccessible and weed-infested country provided that suitable fencing and management practices are implemented. Goats have successfully helped control and/ or have assisted in the elimination of many weeds in Australia including:

- gorse, briar, blackberries
- scotch broom
- saffron, variegated, nodding, spear and artichoke thistles
- serrated tussock

Goats have been used in the management of *Pinus radiata* forests by reducing herbage growth to allow easier access during pruning and thinning, and by reducing the amount of pruning required.

Mohair is a textile fibre used in luxury garments. Produced by Angora goats, it is famed for its lustre and bright colours. It usually commands a premium in prices over wool but it has not had a floor-price to protect it artificially from price depressions. Consequently, prices vary with fashion demand.

Traditionally, the major producing countries have been South Africa, USA (principally Texas) and Turkey. Current production is 11,000 t, a 25-year low, and about half the production of a decade ago. This is in part due to the withdrawal of subsidies in the USA and the slaughter of Turkish goats for meat production. These are strategic changes in the world's mohair industry

which provide a clear opportunity for Australia to overtake Turkey and the USA and become a leading mohair producer in the 21st century.

About the author

Bruce McGregor is a Senior Animal Scientist. Since 1977 his extensive research and advisory programs have developed scientifically based practical management recommendations for mohair, cashmere and goat meat production in non-tropical regions of Australia.

Australian producers have imported the best genetics from South Africa and Texas. Leading breeders are currently developing a unique, new strain of mohair goat that is more productive and robust than the original Australian Angora.

Markets and marketing issues

Australian greasy mohair is sold at auction by several brokers, and most is exported. Mohair is generally exported in a greasy state to Europe, India, Taiwan and Japan. In past years Australia has processed up to 40% of its mohair by either scouring, top-making or yarn manufacture and some finished knitwear was produced. Mohair products such as yarns, rugs, knitwear and velours are imported into Australia.

Recent mohair prices have been significantly higher than during the textile depression of the early 1990s. In 1996 prices eased from their recent peak in 1995. Prices are related to mean fibre diameter, fibre length and the incidence of impurity-medullated or coloured fibre. Fine kid mohair is usually valued at 50 to 100% greater than for the coarser mohair types. Sales in 1997 have seen kid mohair fetch $13/kg greasy and coarser adult fibre average $5 to 6/kg greasy.

Well managed Angora goats are prolific breeders—doe with triplets.

Production requirements

Goats have evolved in semi-arid rangelands where they both graze and browse. This mixed feeding behaviour allows them to consume a wide range of plants including grasses, herbs, scrub and weeds. Goats do not eat everything; in fact they are quite selective, usually choosing only the most digestible plant parts available. They are also flexible and will change their preferences with the season. Goats can be kept on pastures quite satisfactorily but because of their ability to eat a wider variety of plants than sheep and cattle, they are productive in various environments.

Goats prefer areas with between 250 and 600 mm rainfall. When they are grazed with sheep at the recommended stocking rate, there are complementary benefits. If they are grazed with sheep at rates of stocking above the recommended level, they will lose to the sheep, as the goats are not as efficient at grazing the very short pastures. Generally, goats are not adapted to the wetter temperate environments (> 800 mm) where they are more prone to internal parasites and foot complaints.

Like sheep, goats are susceptible to soil trace-element deficiencies, particularly in higher rainfall regions. They may be susceptible to internal parasitism where grazing pressures are constantly > 10 DSE/ha.

Goats require specific fencing similar to that needed for cross-bred ewes. A totally new prefabricated wire fence, in open country, costs from $1500 per km, whereas a 5-line electric fence will only cost about half this amount. In some locations an old fence can be goat-proofed by the addition of one single electric wire supported by outriggers. Electrified fencing is strongly recommended for effectiveness and cost. Shearing facilities are required for fibre goats and yards may need to be upgraded.

Breeds

Angora goats produce mohair. There are several strains of Angora goats including the more productive South African Angoras and the Texan Angoras and the less productive Australian Angoras (see Table 1). Many Australian Angoras are being used in crossbreeding programs with the recently arrived strains. The Australian goats grow finer mohair but the mohair has some other less favourable characteristics. By crossbreeding the Australian goats with the newer genotypes, breeders are selecting a new type of Angora goat more adapted to the Australian environment.

The mohair industry has established a genetic improvement program, 'Moplan', which is available for any producer to join.

It is best to plan your purchases in advance by arranging to buy goats from established breeders. Currently, many potential fibre-producing and breeding goats are slaughtered for meat. Goats are not usually sold in sheep and cattle markets. Specific goat auctions are held at major shows.

Animal husbandry

With your first steps you should 'hasten slowly'. It is strongly recommended that potential goat farmers talk to and visit a number of established goat farms before they buy any goats. Excellent technical information is available from Industry Associations and Departments of Agriculture. Read this information and the proceedings from field days and conferences. Plan your objectives clearly. It is better to start with a smaller number of goats and build up your herd as you improve your management skills.

New entrants must ensure that:

- Appropriate goat fencing is erected on their property before goats are introduced. Fencing is best done by a 'goat-wise' fencer according to industry best practice.
- Goats should be grazed at no more than the recommended stocking rate for sheep in your chosen district. Discuss grazing requirements with the local Department of Agriculture officers. The cheapest feed for all types of goat is pasture. Knowledge of efficient pasture husbandry, fertiliser practices and grazing management will lead to increased productivity.
- Essential equipment includes a vaccinator, drenching equipment, foot-paring shears, ear-tagging pliers, elastrator or castrating equipment, fleece shears and access to shearing equipment and fleece sorting table.
- Planning for shearing, in regions prone to cold, wet weather, includes making contingency arrangements for the provision of shelter to shorn goats for periods of up to six weeks following shearing.

Key statistics

Products	1995/96 Value $ million	
	Production	Exports
Mohair	2.0	2.0[a]

[a] Some mohair is locally consumed and some of the exports are processed.

Table 1. An example of the results of using new Angora genetics in increasing mohair production by crossing Australian with Texan Angoras. The fleece weights (kg) over six shearings are shown. The percentage of Texan blood is indicated (from Davies and Murray 1997)

% Texan	First shearing	Second shearing	Third shearing	Fourth shearing	Fifth shearing	Sixth shearing
0	0.83	1.73	1.78	1.93	1.90	1.85
50	1.15	2.31	2.66	2.85	2.62	3.09
75	0.96	2.49	2.93	3.09	2.74	3.17
100 Texan	1.24	2.82	3.59	3.45	3.11	3.94

- Goats are usually mated in autumn when their fertility is at its highest. One buck can mate about 60 does. Kidding occurs about 21 to 22 weeks (150 days) later. It is usual to mate goats for six to eight weeks and so kidding will be spread out over the same period. It is important to be familiar with the grazing requirements of breeding goats before mating them.
- Planning for kidding is essential. Predators must be controlled before kidding. Provision of suitable shelter is strongly recommended. Cold, wet weather can be fatal for kids.
- Kids are usually weaned from their mothers at 12 to 14 weeks of age.
- It is recommended that does be mated after they reach 25 kg live weight, which usually means at about 19 months of age.

Disease control

Clostridial diseases, especially tetanus and pulpy kidney, can cause large losses with goats. Such diseases are easily and cheaply controlled by vaccinating kids at four to six weeks of age and again four weeks later. An annual booster vaccination is required for all goats.

Grazing goats will be susceptible to internal parasite diseases. It is important to have a thorough understanding of the requirements for the management of internal parasites, both preventative management via appropriate controlled grazing and the requirements for monitoring and treatment. Each district has different environmental circumstances and consequently the actual species of parasite and the appropriate control practices vary. Kids are very susceptible and may need treatment (drenching) with a suitable anthelmintic as young as 10 weeks of age. Drenching 'guns' make the administration of appropriate drugs relatively simple. It is recommended that regular sampling of the faeces of goats for parasite eggs (worm tests) be undertaken to monitor the level of parasitism. Kits to make this task easier are available from Departments of Agriculture. Control programs usually involve treatment of pregnant does at 4 to 6 weeks before kidding.

External parasites such as lice can also infest goats. Control is relatively simple but the equipment needed includes access to a 'sheep dip', either a plunge or spray dip. ALL goats need to be treated twice within 6 weeks to ensure that all adult lice and any newly hatched lice are killed. Special care is needed when using chemicals.

Goats can be susceptible to various foot diseases such as foot rot and foot abscess. Control of these diseases is a medium-term activity following detailed advice from the Department of Agriculture.

Industry groups are trying to eliminating Johnes Disease from flocks of goats. Potential purchasers of goats need to avoid purchasing goats exposed to this disease.

Key messages

- Selling products internationally for 25 years
- Have best mohair genetics in world
- Opportunity to take advantage of changes in international markets
- Established small industry with informed association
- Benefits in pasture and weed management

The more productive new Angora genotypes are being adapted to Australian farming conditions.

Table 2: Gross Margin returns (GM) from Mohair, Wool and Beef Enterprises (adapted from Davies and Murray 1997)

Enterprise	GM per head	GM per DSE [a]	GM per $100 of livestock capital
Mohair (intensive kidding)	$31.38	$14.80	$ 89
Mohair (extensive kidding)	$24.53	$14.35	$ 70
Mohair wether	$14.53	$15.30	$ 85
Merino ewe 21 micron	$26.37	$12.55	$ 95
Merino wether 21 micron	$12.55	$12.55	$ 68
Beef Yearling budget	$213	$12.12	$ 63

[a] DSE = dry sheep equivalent, the feed required for a 45 kg Merino wether.

Harvesting, handling and marketing requirements

Mohair fibre must be shorn from the goats and carefully prepared for sale in order to achieve the best possible financial return. Mohair must be shorn twice each year, usually in late autumn and late spring, when its length exceeds 10 cm. Kid fibre brings the highest prices and so nutritional management and shearing management of kids is critical if the best prices are to be achieved. Vegetable matter (VM) contamination will result in large price discounts. Once the fleece has grown about 3 months it becomes more susceptible to VM contamination. It is important to avoid pastures and hay feeding that will contaminate the fleece with VM or spiny burrs. Shed hygiene standards should be followed.

Mohair must be carefully prepared for sale, contaminants removed and the fibre sorted into sale lines in accordance with the guidelines issued by the marketing agencies. Failure to follow the guidelines will incur additional charges.

Fibre is packed in wool packs, or bales, or in strong polyurethane (clear) plastic bags. These packs must be sealed, clearly marked, coded and numbered and dispatched to the agents with an appropriate dispatch note.

Economics of production

Pure bred goats may cost from $250 per head but commercial fibre goats can be purchased from about $25 per head. If fencing is required, capital inputs will be greater, and this is best undertaken when fencing on a property is already run down. Returns on capital vary from about 0% when significant capital is required to about 40% per annum when benefits arise from weed control.

Key contacts

Industry Associations:
Mohair Australia Ltd
c/- ABRI
University of New England
Armidale, NSW 2351
Phone: (02) 6773 3557
Email: mohair@abri.une.edu.au

In each State the farmer associations have goat industry sections that can provide industry development contacts and information, consult your telephone directory.

Key references

The Goat Manual 1990,NSW Department of Agriculture, Sydney.

McGregor, B. A. (Ed) *Proceedings* National Mohair Conferences, 1994, 1995, 1996 Agriculture Victoria, Melbourne.

Davies, L. and Murray, G., 1997 *The Economics of a Commercial Angora Goat Enterprise* Rural Industries Research and Development Corporation, Canberra.

Brydon, D. (Ed) 1990 *Goat Health and Production* Proceeding No. 134 Post-Graduate Committee in Veterinary Science, University of Sydney, 500 pp.

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- *The Australian Goat Report* published fortnightly and The Goat Farmer magazine, ring 045 761 218.
- *Mohair Australia* published by Mohair Australia Ltd.

Native birds and reptiles

George R. Wilson

Introduction

Many Australian native birds and reptiles have much higher economic value in foreign markets than they have at home. An industry based on them is appealing.

However there are major constraints to the development of an export industry because, notwithstanding domestic trade, the commercial export of all live wild animal species is not permitted. This chapter discusses the opportunities of a native birds and reptiles export industry and the changes that would be necessary to enable it to reach its potential.

A carefully regulated industry should also focus on the conservation of wild species and the reversal of environmental degradation. By enhancing the protection of habitat it could increase the distribution and numbers of wild species. If wild populations have a commercial value, landholders are encouraged to improve the resources on which they depend. Wild species are thus able to compete with non-native species for habitat.

In addition to realising commercial benefits from international trade, controlled trade would reduce smuggling, while allowing pet owners and fanciers personal freedom.

Markets and marketing issues

The international market is large and people throughout the world own birds and reptiles as pets. This meets social needs, improves wildlife awareness and is generally within acceptable animal welfare standards, especially for smaller species.

Australian parrots and reptiles are already sold all round the world. Two species – the budgerigar and cockatiel – are the most popular caged birds.

Some Australian species which are also found to the north of the continent enter international trade after being trapped overseas. Indonesia, for example has a CITES (Convention on International Trade in Endangered Species of Flora and Fauna) quota to export 189,000 rainbow lorikeets; and the Solomon Islands can export 800 *Eclectus roratus*.

Within Australia there is a large, long-established avicultural industry and an emerging herpetocultural industry based on breeding native species. However, these two markets are not connected because of export prohibitions and there are substantial price differences between market values in Australia and overseas. (Figure 1) The price gaps apply both to the less common species such as gang-gang cockatoos and to the very common species – galahs, long-necked tortoises and blue-tongued lizards. There is mark-up of 1600% for gang-gang cockatoos and, most strikingly, 6000% for galahs.

Birds

Commercial-scale breeding overseas is also growing. Tanzania and New Zealand have established captive-bred facilities for galahs to supply the international market demand.

In the United Kingdom, an estimated 4000 parrot breeders produce tens of thousands each year. The most commonly traded birds are the genera *Neophema, Platycercus* and *Psephotus*. Of the larger Australian parrots, the most common species, *Cacatua galerita* and *Eclectus roratus*, are mainly imported from Indonesia according to TRAFFIC (1991). Information on volumes and prices is held by TRAFFIC, the International Union for the Conservation of Nature (IUCN) and the World Wide Fund for Nature (WWF) agency. However much of it is anecdotal.

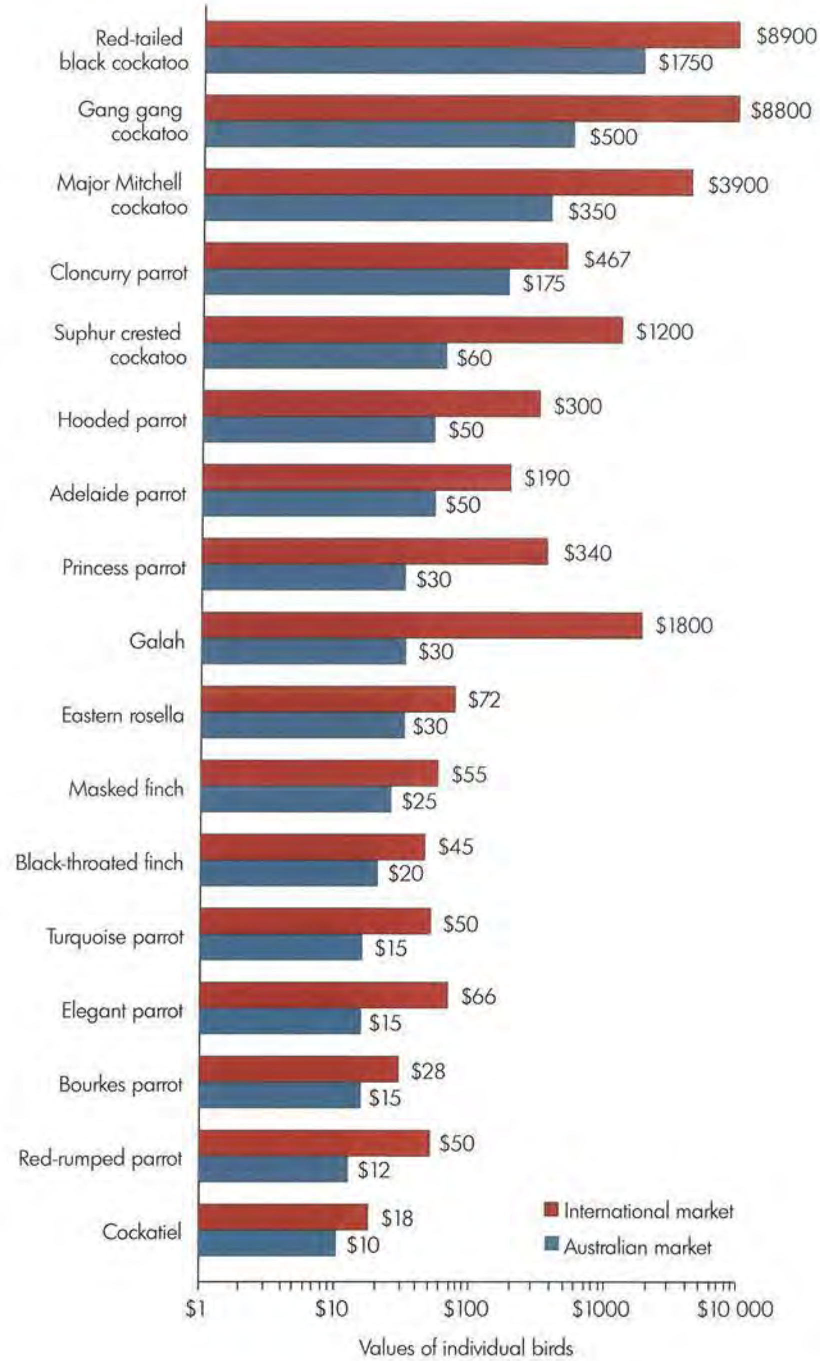

Figure 1. Comparison of bird prices on the international and Australian markets (note logarithmic scale)

About the author

Dr Wilson has a long background in wildlife management and emerging industries. His basic training was as a research scientist. and he has had over 25 years experience in public policy and strategic analysis, particularly in emerging regional industries and indigenous economic development. He has recently worked with ACIL Economics and Policy Pty Ltd on a range of economic and resource use issues. Before that Dr Wilson was executive manager of research projects in the Bureau of Resource Sciences and at other times had extensive contact with the practical application of research work through assignments for the rural R&D corporations. See *Key contacts* for address.

Reptiles

Price differences for reptiles are generally not as wide.

The Australian herpetocultural industry is not well developed and the prices for species which are harder to breed such as the green python are actually higher in Australia than they are overseas. (Figure 2) Overseas expertise in breeding of reptiles is greater. There are nevertheless some significant export opportunities. Market prices for blue-tongued lizard are 800% higher overseas and long-necked tortoises 300%.

The industry expects herpetoculture to increase in popularity, with ever more naturalistic and larger displays to satisfy more sophisticated and ecologically-oriented clientele. The aim of the US industry is to have a herpetological display in every living room, or at least every living room that would consider having a tank of fish. The herpetological industry sees the transition as similar to that which affected the aquarium industry when it changed from a speciality hobby to a mainstream pastime.

Constraints to growth in wildlife markets

Despite the commercial opportunities, there are considerable constraints on growth in wildlife markets. Commercial use of wildlife is an emotive subject and in 1997 was the subject of a Senate Inquiry. Those who wish to maintain the trade barriers have moral concerns about interfering with native animals and their rights to roam or fly free. They are concerned about animal welfare aspects and the suffering which commercial use inflicts on animals. They also fear that trade will aggravate the threat to endangered species.

Public opposition to trade in wildlife influences the policy of the Federal Government and the growth of the industry is therefore inhibited by the need to win public acceptance of commercial use.

Production requirements

There are two opportunities for the development of the domestic industry into an export industry. Both aim to produce live birds and reptiles for use as pets and for bird and reptile fanciers. Both are based on known techniques and procedures tested by the established avicultural industry and an emerging herpetocultural industry. Rearing of larger species in captivity – emus and crocodiles – is also proceeding for agricultural production and is accepted by the community.

One production system involves the intensive breeding of birds and reptiles in captivity. The other involves the harvesting from the wild of juveniles and rearing them in captivity – a ranching operation as defined by the CITES. The latter production system would focus on the more valuable species that are difficult to breed in captivity. It would require that landholders maintain habitat and control predators on their lands. The outcome would be of benefit both to populations of the species being targeted and to other species that depend on the same habitat.

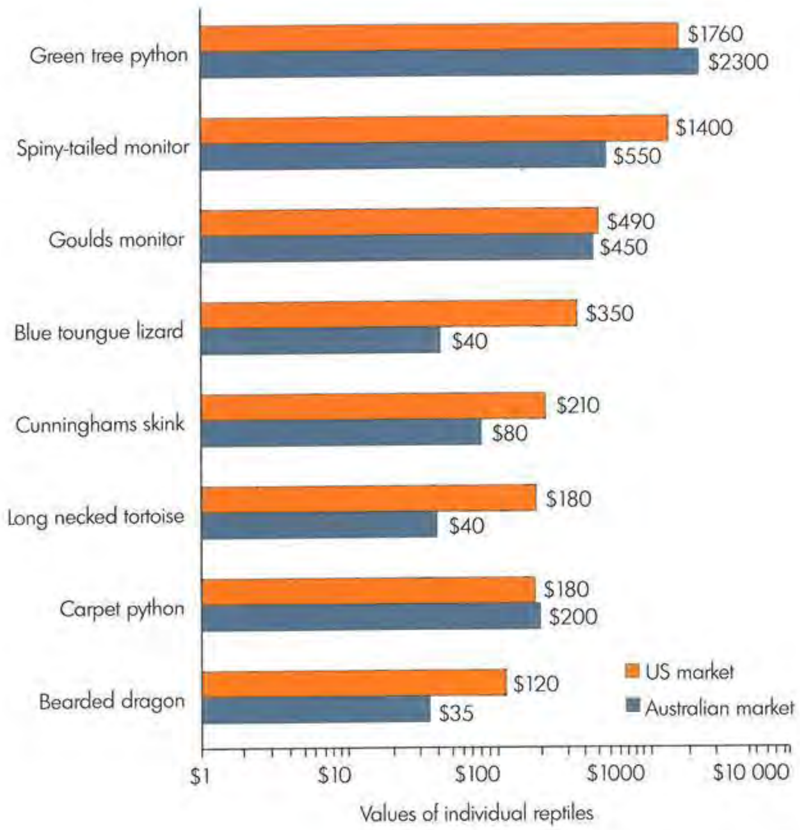

Figure 2. Comparison of bird prices on the international and Australian markets (note logarithmic scale)

Key statistics

- Common birds and reptiles are up to 60 times more valuable overseas than here.
- More than 1 million Australian households have birds as pets and annual expenditure on them is estimated at more than $150m.
- More than 200,000 'Australian' parrots are traded from Indonesia per year under CITES controls.
- In the U.K. alone there are more than 4000 breeders of Australian parrots.

Galah (*Cacatua roseicapilla*), adult male: Chambers Gorge, Flinders Range, SA. Credit: Ross Whiteford/ Nature Focus.

Current management regimes for Australian birds and reptiles administered by States and the Commonwealth would need to be altered to allow the export of specimens of a limited range of species in a pilot or feasibility study. Strict controls are needed to meet the community concerns referred to above.

Species

The first opportunity focuses on captive breeding of smaller species which are currently in commercial production in Australia and overseas and to which animal welfare concerns are less likely to apply. These include:

- budgerigars and cockatiels;
- long-necked tortoises, blue-tongued lizards; and
- Adelaide, Cloncurry and hooded parrots.

The second opportunity involves harvesting surplus young from the wild with a view to hand-rearing in captivity ('ranching'). This opportunity has considerable scope for Aboriginal people. Species of potential include:

- galahs, sulphur-crested cockatoos; and
- goannas and carpet pythons.

At a later stage, ranching operations could be extended to less common species, but only as part of a management plan that includes prior habitat improvement, mortality control and agreement to release back to the wild. This opportunity could include less common species such as:

- gang gang, Major Mitchell and red-tailed black-cockatoos;
- birds of prey such as peregrine falcons;
- cassowaries, bustards; and
- other tortoises, pythons, geckos and frogs.

Key messages

- Keeping pets brings joy to people, improves wildlife awareness and is generally within acceptable animal welfare standards.
- Australia is missing the opportunity to supply the large international pet trade.
- The Australian avicultural industry has the technical skills on which to base an export industry.
- Galahs and long necked tortoises are being bred overseas.
- A policy change should allow pilot and feasibility study of export of common species.
- The proposal **must** be linked to habitat preservation and means of increasing conservation of rarer, more valuable species

Management and husbandry

The technical aspects of the husbandry of birds and reptiles are relatively well known. The stages in the process are trapper or breeder – dealer – transport – quarantine – dealer – wholesaler – pet shop and owner. The chain for overseas sale is longer.

The main concerns are ownership, commercial sale, compliance with community standards and management. Australian policies, laws and procedures dealing with the keeping, trade and conservation of wildlife are very complex. They consist of overlapping State and federal laws to protect animals and control trade; preservation of areas of habitat in national parks and reserves; and programs and schemes for safeguarding habitat outside the reserve system.

Australian laws enable Aboriginal and Torres Strait Islander communities to use native flora and fauna on their land for their own consumption but they can not sell wildlife. Even the sale of an animal to another person within an Aboriginal community is not exempt.

Export control laws

Captive-bred products. Private and commercial trade in wildlife products, but not live animals, is permitted if the products are derived from captive-bred animals or artificially propagated plants. Australia has an established export trade in skins of captive-bred crocodiles, emu products, artificially propagated native plants, including orchids, and captive-bred native butterflies and fish.

Wild-harvested products. Commercial trade in products of animals and plants taken from wild populations is also permitted, provided the species is not listed on Appendix I of CITES and is not a member of the cetacean group (whales, dolphins, porpoises), where a management program has been approved under the Act, or the specimen has been declared a controlled specimen. Management programs currently allow the export of products derived form a range of species including kangaroos, brush possum, mutton-birds and wildflowers from Western Australia.

The export of wildlife also has to comply with the CITES (see box) and the powers the Commonwealth derives from it under the Wildlife Protection Act. These affect both the development of intensively managed wild animal 'farms' and the extensive harvesting of native wildlife species. For export to proceed, management plans must be prepared.

Animal welfare standards for the care and keeping of birds and reptiles that cover capturing, transporting, sale and keeping are promulgated by State jurisdictions. They stipulate codes for husbandry, feeding, water, accommodation, minimum cage sizes, health and quarantine processes. In some States these codes are backed up with the power of legislation.

Stress on wild-caught birds

It is sometimes suggested that capturing wild birds that are a nuisance and selling them will solve pest problems. However, capturing adult birds can be cruel particularly if they cannot adapt to captivity and transport. These animal welfare issues need closer examination. Young, hand-reared birds which are tame and easily handled make the best pets and are most sought-after. The larger companies that sell wild birds in the domestic market state that although birds are trapped all the year round they make it a practice to sell only young birds suitable for taming and training.

Convention on International Trade in Endangered Species (CITES)

Under CITES, more than 124 nations are now regulating international trade to prevent the decline of species threatened or potentially threatened with extinction. Trade, which is defined as import, export, or re-export, of a long list of such threatened animal and plant species, is either virtually prohibited (Appendix I species) or restricted (Appendix II or III species). The Convention requires that international shipments of these species, and products made from them, possess an import or export permit, or both, issued in advance by the official management authorities of the countries involved. Permits are issued after findings by scientific authorities that the trade will not be detrimental to the survival of the species in question.

Eastern snake necked or long necked turtle *(Chelodina longicollis)*.
Credit: G. Little/Nature Focus.

Adult, wild-caught birds can make reasonable pets if experienced or dedicated bird trainers handle them. However it is much more difficult to train an adult bird that has no human contact, or worse, negative human contact, than it is to bond with a baby that has only ever had positive contact with humans.

Pests and diseases

Wild-caught birds could succumb more readily to diseases. The stress of trapping, collective housing and distribution leads to the suppression of their immune systems. Clinical presentation of psittacine beak and feather disease (PBFD) and infections due to enterovirus, psittacosis virus, gram negative bacteria and occasionally megabacteria and polyomavirus are more likely. Older birds are more likely than younger birds to be carriers and transmit disease to other birds at the dealers, pet shops or eventually the destination aviaries.

Effective quarantine is necessary to ensure that exports do not expose foreign birds to Australian diseases. Countries importing birds and reptiles are likely to require rigorous pre-export testing and certification of health status in order to protect their own birds. PBFD is believed to have appeared in South American psittacines in North America after they were exposed to birds of Australasian origin. Further introductions of Australian psittacines could increase the risk to rare and valuable birds.

Imports to the USA of some species of animals and from some countries are prohibited; others must be held in USDA animal import centres or quarantine stations for 30 days after entry and inspected by veterinarians of the Animal and Plant Health Inspection Service (APHIS).

Transport and welfare

Many thousands of birds are currently exported from Australia including wild-trapped exotic green finches, gold finches and canaries, and Australian species exported as bonafide pets. These birds are subject to IATA Live Animal Regulation and most to CITES regulations. All parrots except three are in CITES Appendix II or higher. (see box above)

CITES requires importing countries to note and comment on the health of imported birds; any suspicion of disease; whether the type of box and its construction correspond to IATA prescriptions, are overcrowded or the boxes damaged; ventilation problems; or lack of water/food. Mechanisms are available for reporting back to the CITES Animals Committee.

Public concern about smuggling has led to many policy initiatives and reviews. It is also the focus of much of the enforcement of the Wildlife Protection Act. TRAFFIC is a non-government agency which also collaborates in these efforts.

The transport of birds and reptiles is given a poor image by revelations of cruel smuggling. Ironically, one step in reducing the cruelty is to allow commercial trade, remove the incentive and bring trade under the control of existing codes of practice.

Economics of production

The size of the Australian domestic market is already substantial. More than 1 million Australian households have birds as pets and expenditure on them is estimated at more than $150m. Some of these are exotics such as canaries or peach-faced lovebirds.

The production industry is also large. In WA for example, there are at least 4300 aviculturists, 100 bird dealers and three licensed trappers. Individual bird collections can be very valuable; some are worth over $1 million each.

Many bird and reptile species could be profitably exported. An industry could build on Australia's unique genetic resources and the international demand for progeny.

Australian producers have an edge over competitors in regard to the price differentials of the initial breeding stock and its availability and fitness. Another commercial advantage comes to Australia from the difficulties overseas breeders have in emulating Australian conditions and other costs of producing the birds. For example, cold winters and cool to mild summers in the UK can create difficulties for some species. Imported bird-seed prices do not compare favourably and suitable land is not as readily available at a reasonable price.

In more spacious enclosures, Australian costs of production could be minimised by exporters concentrating on single species and developing specialised breeding procedures, (as is being done by the breeders of galahs in Tanzania). The current practice in Australia is to breed a variety of orders and species more intensively..

Some international competitors such as Birds International in the Philippines may provide considerable competition when they target markets with low animal-health standards. However, the relatively high avian health standards and certification procedures in Australia may facilitate the export of birds to countries with correspondingly high standards of avian health, such as Scandinavia.

There seems to be little prospect for exporting low-value birds such as budgerigars and cockatiels. Captive-bred birds overseas are closer to their destination, have less time in quarantine and in the wholesale/ retail channels, and so receive positive human contact sooner after they fledge.

Pest birds could be exported at minimal cost but the market demands pet birds in good condition. Wild-caught cockatoos that are currently sold for the domestic market are young animals; older birds have less market value because they squawk and might bite.

Effects on the Australian industry of access to overseas markets

The export of captive-bred birds could generate export revenue and local employment. It would benefit aviculturists, farmers and entrepreneurs who may wish to enter the trade. Some Australians in the industry, however, are opposed to a change. They are concerned that Australian prices would rise to the international levels. Major Mitchells, for example, could rise in value to $1200. Others see it as our salvation, noting that the Australian market has been suffering from over-production and prices have been falling. For example, hooded parrots which were worth thousands of dollars 20 years ago now fetch $80 per pair.

There is hardly any purely commercial activity in reptiles in Europe. In the US trade is more substantial. Size and other attributes are important to the value of a specimen. Snakes are also valued for producing venom.

The provisions and requirements of CITES in regard to ranching, breeding species in captivity and transport should be used as the minimum criteria set to test a pilot study of the commercial export of Australian birds and reptiles. A project is needed to develop the details of the proposed management regimes. It would outline habitat improvement procedures that deliver enhanced conservation status and recommend methods for determining the numbers of surplus animals available for harvest. Birds trapped for pest control suffer stress and present animal welfare concerns. They are unlikely to make good pets and the activity is not recommended.

Key contacts

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The ostrich industry

Chris Tuckwell

Introduction

The ostrich industry in Australia has its origins in South Africa where ostriches have been farmed commercially since the 1860s. Before then the only way ostrich products could be harvested was to hunt and kill the birds.

Domestication of ostriches began in the 1860s to prevent the extinction of the birds from over-hunting. The South African ostrich industry, originally based on feathers, declined in the early 1900s but revived in the late 1960s thanks to an increasing interest in ostrich leather. The industry has grown slowly in South Africa since 1970. Since the late 1980s, it has grown rapidly in many countries outside South Africa including Australia, New Zealand, USA, Canada, Europe and China.

The principal products of the current world ostrich industry are leather and meat. Other products include oil, feathers and eggs.

According to the best available knowledge, there are no religious, social, traditional or cultural limitations on the consumption of ostrich meat. Thus access to markets is limited (apart from tariffs and embargos) only by marketing skill, product quality and price, and consistency of supply. The leather is regarded as a high-quality, uniquely patterned product well known for its durability.

Both products are expensive in comparison with competing products. The industry's greatest challenges are to develop new markets as other countries begin commercial production and to maintain the high value of its products as the overall volume of production increases.

The ostrich industry has spread throughout Australia but its largest concentration is in central Victoria and southern New South Wales.

Markets and marketing issues

The ostrich industry in Australia, being fairly new, is (in 1997) moving from a being a speculative undertaking based on individual breeders to one based on commercial production.

In 1993 the industry saw that it needed processing facilities, quality assurance systems and market opportunities before it could produce in commercial quantities. As its marketing arm, the industry formed the Australian Ostrich Company (AOC) which, since 1993, has been actively developing processing facilities and

initiating market development as well as establishing 'gate to plate' quality assurance programs.

As the principal markets for Australian meat products are likely to be in Europe and Asia, the AOC is concentrating marketing efforts for meat and leather products in those areas. The USA is also a target for leather products.

Production is still small, but increasing. Estimates show that at least 5,000 birds will be processed in 1997 and up to 30,000 may be processed in 1998.

The current international price for prime ostrich fillet is AUD$10.00 to $15.00 per kg at farm gate. Prices for ostrich leather range from US$30.00 to US36.00 per square foot (US$330 to US$385 per square metre).

Production requirements

The natural home of ostriches is the arid regions of South Africa. The birds can be managed in most climates, but chicks are extremely susceptible to cold and humid environments are not ideal. Birds of all ages produce well on green pasture (particularly lucerne) provided that their ration is balanced by supplements. Birds can be managed with diets that are completely supplied (no grazing).

Breeding birds appear to be more productive when managed in hot, dry environments, so much of Australia is suitable. Other factors such as the cost of transporting birds and feed strongly influence the ideal locality for growing birds for processing. Hot dry environments which have access to water for irrigating pastures and are close to processing and feed-production areas could be considered ideal. Ostriches prefer flat land or gently rolling hills

The Masai or East African 'red neck' ostrich.

About the author

In 1978 Chris Tuckwell RDA RDAT graduated from the University of Adelaide's Roseworthy campus. Until 1996 he worked for the South Australian Department of Primary Industries (PISA). From 1990 he led New Animal Industries group. He now works for Rural Industry Developments Pty Ltd whose activities include: assistance with industry and enterprise development; the provision of technical and marketing advice; and research and extension programs. See *Key contacts* for address.

Breeds

Common, commercially recognised ostrich names are Blue Necks, Red Necks and African Blacks. The description Red Neck usually refers to the Masai ostrich from East Africa.

The description Blue Neck usually refers to Somali and South African ostriches and the African Blacks are a stable cross-breed of the South African and Barbary ostriches of North Africa.

> ## Key statistics
>
> - Approximately 120,000 ostriches are farmed in Australia (March 1997)
> - 100,000 birds could be available for slaughter by 2000
> - Specialised slaughtering facilities exist for ostriches

Within each of these descriptions, physical characteristics can vary significantly between locations

All ostrich breeds are available in Australia. Selection of breed or breeds depend on the production program a manger intends to follow. In principle, commercial production is likely to emulate other industries where pure breeds are maintained and interbred to make the best advantage of hybrid vigour in stock bred for processing.

Animal husbandry

Ostriches in Australia are usually managed intensively. They require specialised fencing along boundaries and the internal fence structures for birds over 12 weeks are different from those used for other stock.

Breeding birds especially appear to be more productive in climates similar to those of South Africa (hot and dry). Diet formulation is important and strongly affects performance Pasture is an ideal complement to prepared rations for growing stock and while birds are principally fed prepared rations, high-quality, short pastures (particularly lucerne) can reduce feed costs. It is accepted that an ideal feeding regime requires six different rations: 0 to 2 mths; 2 to 4 mths; 4 to 6 mths; 6 to 10 mths; more than 10 mths including maintenance; and a breeder ration.

The Somali or South African 'blue neck' ostrich.

Young birds are very susceptible to cold, stress and disease if they are not managed properly but they grow rapidly when well fed and managed.

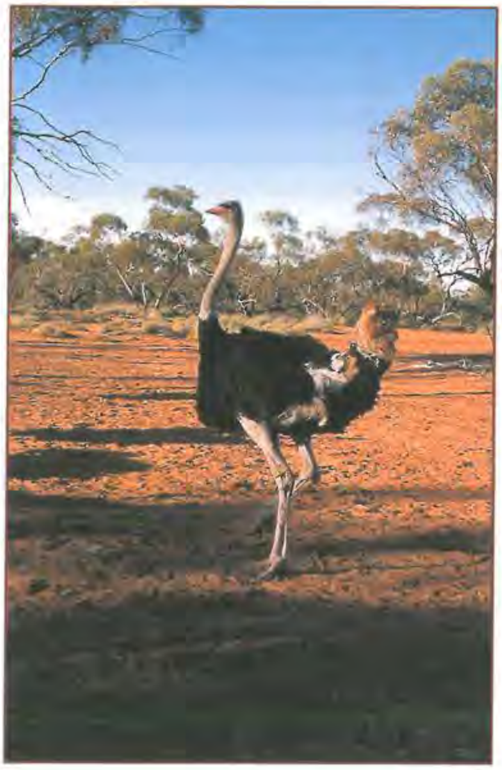
The breeding season in Australia extends from about August to March. Bird are usually bred in pairs, trios (one male and two females) and sometimes in colonies (large groups of males and females).

To be economically efficient, hens in commercial production enterprises should produce 15 to 20 chicks that survive to yearling age annually. Birds for processing must reach a slaughter weight of 95 to 100 kg before 14 months of age.

The correct management of ostrich farms is not difficult to learn, but people should not enter the industry without an understanding of the minimum requirements for the welfare of ostriches and should ensure that they have access to an industry specialist before they purchase stock.

Diseases

All livestock can be susceptible to infectious, non infectious and metabolic (nutritional disease) and ostriches are no exception.



The African 'black neck' ostrich.

Disease control programs should include vaccination, internal and external parasite monitoring and control, feed quality controls, and routine bird assessments.

The method of transmission of disease between ostriches can vary. It is often introduced by human movement between groups of birds or by the introduction of infected stock or stock which are not infected but carry a disease. Domestic poultry are thought to be a common source of disease in ostriches, so it is prudent for ostrich enterprises to be well isolated from all other poultry.

Most diseases can be related to such farm management practices as feed and water supply; climatic and other stresses; hygiene; and incubator/brooder management.

Chicks from hatching to six weeks of age are most susceptible to bacterial infection of the digestive tract and when infected are likely to die. Management practice must reduce risks arising from hygiene, temperature control, and feed.

Birds of all ages will eat debris including pieces of metal, glass and coins. These objects can cause internal injury, poisoning or compaction. It is important that sites are kept clean. Small sticks and twigs cause similar problems for young chicks.

Inappropriate feeding can also cause problems. It is important that rations provide the recommended protein, energy, fibre and calcium (especially for breeding hens).

Processing

In general, the highest quality product is produced from birds more than nine months and less than 14 months old with a live weight of more than 95 kg. The quality of skin on over-fat birds is generally poor.

Birds destined for slaughter should travel to lairage in transports designed for ostriches and ideally spend at least one day in lairage yards before slaughter. They are processed in a similar manner to other livestock apart from the need to remove the feathers before skinning.

Most meat marketed internationally (South African) is frozen. Until recently, the meat was regarded by the South Africans as a secondary product and the processing, packaging and marketing were poor. A result of the AOC's meat marketing program, the meat is now regarded as a product of similar importance to skin.

Meat is usually traded in individual cuts, although there is interest in whole carcase from Asian traders. The AOC has also developed a range of smallgoods products that add significant value to the ostrich trim (a world first).

Key messages

- The industry is growing rapidly both in Australia and internationally
- It is essential that market growth matches production growth
- Australia is leading the development of ostrich processing technology
- There is a market both for meat and for highly-valued ostrich leather

At a conference in South Africa in February 1997, a new ostrich-meat language and description of meat cuts was accepted as the international standard. Ostrich meat compares favourably with other commonly consumed meat and it has a relatively low fat and cholesterol content.

An ideal slaughter bird typically produces 1.3 to 1.5 square metres of leather. Skins are sold by the square foot and are graded as either first, second or third grade according to quality and damage. The international market for ostrich leather is still strong and product prices remain very high even in South Africa (the world's largest producer).

Ostrich oil has been largely overlooked by the South Africans. An Australian company has developed a range of ostrich-oil cosmetics which is slowly gaining market acceptance.

Economics of production

As technologies change and the industry increasingly relies on sale of commercial product for its profit, economies of scale will change. Current budgeting can reasonably determine guide costs of production, but estimates of income need to predict future prices in comparison with the current ones, taking into consideration the likely price movements as international production increases.

It is important that all gross-margin budgeting considers the farm-gate sale price for birds destined for processing and does not assume that the return to producers is a sum of the marketed value of the products.

The table below is a Guide Budget for a Self-Replacing Ostrich Flock of 50 breeding hens that produce an average of 15 live yearlings per hen. The enterprise will require approximately 50 hectares of land and an estimated total setup cost of $251,000.

Self Replacing Ostrich Flock (50 hens)			
Income $			
742 growers	@ $450 ea	$333,900	
6 culls	@ $150 ea	$900	
620 infertile eggs	@ $2.00 ea	$1,240	**$336,140**
Expenses			
Interest on capital		$25,173	
Feed/water		$133,424	
Labour		$57,600	
Repairs/maintenance		$12,587	
Freight		$14,960	
Veterinary		$4,932	
Heating		$10,000	
Identification		$932	
Contingency		$12,975	**$272,482**
Gross margin			**$63,558**

A suggested minimum economic size for this type of enterprise is 30 breeding hens. New entrants to the industry may find the costs of establishing alternative ostrich enterprises more appealing, especially since, although most of Australia's current ostrich enterprises undertake all aspects of ostrich production and usually on one site, in future they are likely to specialise in one aspect of production or at least undertake each phase of production on separate sites.

The range of alternative enterprises includes: breeding enterprises that sell fertile eggs, chicks, yearlings or a combination of the three; enterprises that incubate eggs; enterprises that rear chicks to 8 to 12 weeks; and enterprises that grow chicks to slaughter age.

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Sheep milking

Roberta Bencini
Stan Dawe

Introduction

Australia has an established home market for sheep milk products in which the products traditionally sought are cheeses and yoghurt. There is also a large international market and a strong overseas demand for disease-free milking sheep, which eventually can be supplied from Australia.

The Australian sheep dairy industry is currently centred on Victoria, with seven dairies, and one each in South Australia, Western Australia and New South Wales.

Most sheep milk is produced in the Mediterranean Basin (Table 1). New producers are the US, Argentina, New Zealand and Australia, but their levels of production are as yet insignificant globally. Australia is a world leader in the husbandry, breeding, and advanced technology of sheep production so it is well placed to be the most efficient producer of sheep milk in the world.

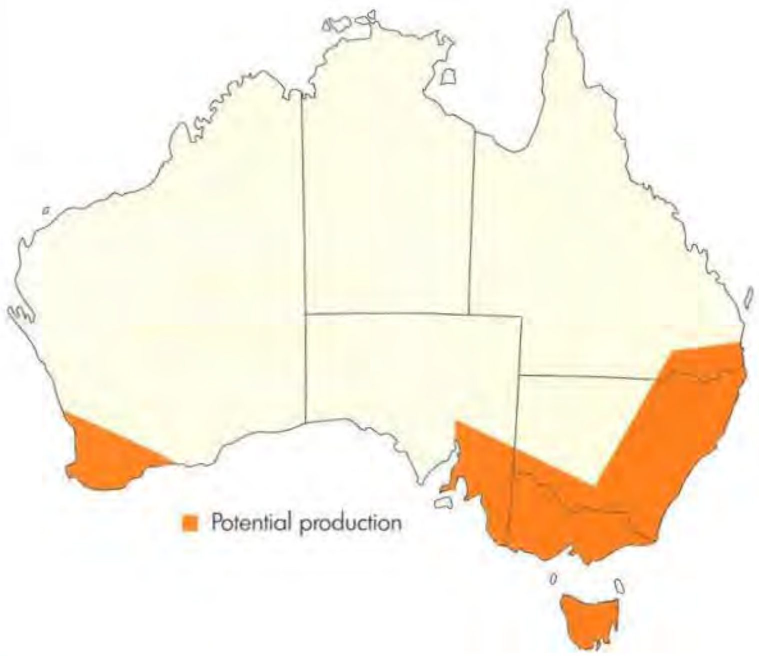
The skill required for sheep dairying are experience in sheep husbandry, pasture management and dairy management. Early venturers marketed and distributed their products directly, but this will probably change as the industry develops and a more efficient infrastructure emerges.

Markets and marketing issues

The Australian sheep dairy industry has had a difficult history. Many operators, both milkers and processors, have ceased, mainly because of difficulties in developing markets. This has generated inconsistency of supply on some markets so there is a need to restore confidence in the supply.

Sheep dairy farmers can sell the milk to dairy manufacturers, or establish a vertically integrated enterprise. Farm-gate returns for sheep milk are $1.20–1.50/litre. A vertically integrated enterprise generates higher returns, but there are higher capital costs and inevitable problems when establishing a sheep-milk processing factory.

There is a limited market for pasteurised sheep milk, mainly to health-food outlets. Of all the milks, it has the highest retail price (up to $5/litre). High returns are also achieved when processing the milk into yoghurt: with a yield of 100%, pot-set yoghurt fetches retail prices of



up to $6/litre. The demand for sheep milk yoghurt typically peaks in summer, when sheep milk is scarce. Some sheep dairy farmers produce yoghurt from frozen milk, which is suitable for the production of dairy products.

Table 1. Production of sheep milk (1000 t) from the 10 top producing countries (source: FAO, 1996). These 10 countries produce 54% of the world's total.

Turkey	921,500
Italy	799,900
Greece	670,000
Syria	450,000
Romania	393,600
Spain	313,200
Algeria	220,000
France	217,946
Bulgaria	123,700
Portugal	97,000
Total	**4,206,846**
World	**7,756,448**

About the authors

Roberta Bencini BScAgr, PhD is a lecturer at the University of Western Australia. She did her undergraduate studies in Italy, where sheep dairying is an ancient tradition, and her PhD at the UWA. She directs a sheep milking research project supported by the RIRDC.

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Stan T. Dawe BScAgr, MSc is Salt Action Coordinator with NSW Agriculture at Yanco. He has 30 years experience in grazing of irrigated pastures, control of reproduction, artificial rearing and lot-feeding of lambs, sheep dairying, and accelerated lambing systems. He managed a commercial dairy for three years, milking up to 1,000 ewes daily in a 32 unit rotary parlour.

Liquid milk and yoghurt provide the cash flow for sheep dairies as most cheeses need to be stored because they vary in their maturation times.

A strong local market is essential for the success of sheep dairies: sheep milk products are generally of high quality and the public readily accepts them, but it is important to let the public know that these products are available. Promotions at shopping centres are probably the best way to achieve this. The fact that gourmet products and boutique cheeses are in high demand is an advantage.

There are also potential export markets for sheep milk and its products. Several outlets are possible for frozen sheep milk in large quantities, and for cheeses and yoghurts. However, the quantities required by these markets are generally too large for the small Australian sheep dairies.

Production requirements

Sheep dairying can be conducted in any region of Australia that is suited to prime lamb production. Location should take into account the proximity to markets and the ability to produce feed for the periods of joining, late pregnancy and lactation that are desired for the operation.

Feeding during lactation can be provided by good quality, legume-based pasture or by prepared lot-feed rations. An elevated, well-drained area is ideal for the milking facility. There must be adequate clean water, and at least 10 KVA power, preferably with 3-phase. There are also regulations which specify how close the dairy can be to other buildings (poultry sheds, pig houses, shearing sheds, machinery sheds), to reduce the risks of contamination and assure highest quality milk. However, these regulations may vary from state to state.

If sheep are being milked off pasture, the maximum distance they should walk is 500 metres.

The dairy should therefore be located centrally to milking paddocks. Shade trees and fresh water should be available in these paddocks.

Varieties/breeds

Until recently Australia did not have a specialised breed of dairy sheep. Table 2 shows milk productions and lactation lengths of several overseas breeds.

The sheep which stand out as dairy animals are the East Friesian and the improved Awassi. Both breeds have been imported into Australia and farmers could purchase semen from Friesian or Awassi rams to inseminate ewes of local breeds. Friesian semen is readily available, but limitations apply to the purchase of Awassi sheep.

Within the local breeds none excels for dairy production, even though any breed can have individuals with exceptionally high dairy yields. The Poll Dorset is very tame and some ewes have high milk yields. The Border Leicester has high peak yields but is famous for its bad temperament. The Merino is very shy and difficult to train; it has low daily yields and short lactations making it a good breed to produce wool, but not milk.

The Hyfer Sheep was developed by NSW Agriculture for specialist lamb production from Dorset, Merino Booroola and Trangie Fertility. About 10% of Hyfers milked in the NSW Agriculture research dairy at Leeton from 1985 to 1990 had yields of 150 litres or more per lactation.

Sheep Husbandry

A sheep dairying operation should be planned carefully. Some of the points to be considered are:

- Where to sell the milk and at what price
- How many sheep and what breeds to milk
- What feeding system to adopt (e.g. shed/feedlot or pasture)
- Whether milk is to be produced year round or seasonally
- What breeding program to adopt

Table 2. Milk yields and length of lactation of overseas dairy sheep

Country	Breed	Dairy yield (kg)	Length of lactation (days)
France	Lacaune	200	100–210
Europe	East Friesian	600	260
Spain	Manchega	50–125	–
	Churra	45–75	170
Italy	Massa	150–160	180–210
	Sarda	250	170–240
Bulgaria	Stara Zagora	–	–
Holland	Texel	150	150
Israel	Assaf	350	120–210
	Improved Awassi	400–450	120–260
Syria	Awassi	70–90	120–180
Portugal	Serra da Estrela	110	200–230
Czechoslovakia	Tsigay	50–90	180
Greece	Chios	270	220

Awassi (fat tail) sheep are noted for their milk and meat production.

- Management of the lambs
- Type of dairy and labour requirements.

There should be a secure outlet for milk, offering at least $1.20/ L, and close enough to minimise transport costs.

The number of sheep will depend on several factors, e.g. if it is a sideline or main enterprise; on the size of farm or shed; and on capital and skills resources.

The choice of shedding or grazing depends on capital, personal preferences, and existing resources. Shedding is capital-intensive but offers easier operation of milking, and simplified worm and fly control, and feet care.

Milking year round requires a careful reproductive program for lambing at regular intervals. The longer the lactation, the less intensive the breeding program could be. Some breeds are lambed every 8 months, with groups staggered to give a lambing every 1 or 2 months on the property.

Lambs can be removed at 1–3 days of age and reared artificially. Ewe lambs are grown out for replacements, while males are usually sold to others for rearing or euthanased. Alternatively, lambs can be left on the ewes until 4–6 weeks and then weaned, but this involves losing some milk. Systems of share-milking, consisting of allowing the milking ewes to nurse their lambs, are under study at the University of Western Australia.

Year-round feed can be supplied by pasture in the higher rainfall areas, irrigated pasture, or by lot-feeding. It is important to have sufficient feed supplies for sheep outside the milking flock such as pregnant ewes, weaners, replacements, and dry ewes.

The type of dairy will depend on the numbers to be milked and the capital outlay. While large rotaries are capable of milking 400 ewes hourly, they are costly and difficult to maintain. Herringbone parlours can be as efficient as rotaries, have fewer maintenance problems and need less capital investment.

Pest and disease control

A disease that can affect dairy sheep is mastitis, an inflammation of the udder caused by infection of the mammary tissue. Mastitis reduces milk production and mastitic milk is unsuitable for processing.

Mastitis should be prevented, rather than cured, by ensuring that the milking machine is operating properly and by disinfecting the teats after each milking. Vacuum fluctuations, excessive levels of vacuum or leaving the milking cups on too long can cause over-milking which can lead to mastitis. Disinfection after milking prevents the entry of mastitis-causing bacteria in the teat canal, which is naturally enlarged after milking.

If mastitis occurs the sheep must be treated with antibiotics either locally (with products that are infused into the mammary gland) or systemically (intramuscular injections) and the milk must be kept separate from the processing milk.

Foot problems frequently occur in high rainfall areas (footrot, foot scald, foot abscess) and can seriously affect milk production.

Worms and other parasites are a problem because milking sheep should not be treated with chemicals that could be translocated into the milk. Captec extender 100 is suitable for use in a dairy because the drench is released in small doses, and levels in milk do not exceed the EEC recommended limits.

Sheep must be trained to walk onto the milking platform generally by rewarding them with feed.

Ideally, parasite control should be done when the ewes are dry, and translocation of any residues into the milk cannot occur. If chemicals have to be used, withholding periods prescribed for dairy animals should be adopted.

Milking, handling and processing

Sheep are milked twice a day, but in some cases one milking per week can be skipped without affecting production, or milking can be reduced to once daily towards the end of lactation, when yields are low.

The sheep must be trained to walk on the milking platform, generally by rewarding them with feed. Feeding on the platform also keeps the sheep occupied and quiet during milking and it allows the administration of concentrates, which are an integral part of the diet if the sheep are grazed on pasture.

In the dairy, it is important to follow a routine at every milking and to be gentle with the animals. Fear and stress cause the production of adrenalin, which blocks the action of the let-down hormone (oxytocin) so that the milk is not let down and yields are low. Therefore dogs, strangers, loud noises and other stresses should be avoided in the dairy.

Health regulations vary from state to state, and farmers should contact the relevant dairy authorities before getting started. In some states sheep are not classified as a dairy animals, and following dairy industry regulations is not strictly required. However, our advice is to follow the rules regardless. Milk is an exceptional food source not only for us, but also for harmful bacteria that can cause serious human diseases. To avoid high bacterial counts, hygiene is essential in every aspect of the operation. Hygiene of the milking plant involves disinfection of milk cups and milk lines after each milking, following the recommendations of the supplier of the milking plant.

The milk should be cooled to <5°C soon after milking and pasteurised before processing. Some people maintain that pasteurisation alters the beneficial properties of the milk, but there is no scientific evidence for this.

Sheep milk can be processed into any dairy product. Most dairy products are made by adding selected starter cultures to the milk and most cheeses are made by curding the milk with rennet. There are hundreds of different cheeses and the main factor that produces variation is the technology: cheese-makers will vary the outcome of the cheese by changing the amount of rennet added, the type of starter culture, the temperature of coagulation, the time of maturation, and so on. It is difficult to give advice on what products will be most popular. In general the fresher the product the higher its yield from each litre of milk, the faster its turnover and the cash flow to the manufacturer.

Economics of production and processing

Getting started can cost anything from $50,000 to $500,000. For a hobby-farm operation it could cost as little as $50,000 to build a small herringbone parlour to milk 100–250 ewes. At the other end of the scale, half a million can be easily spent to build a large rotary dairy to milk up to 3,000 ewes and an attached cheese factory to process the milk. It is difficult to give advice on what will work as it will depend on target markets, type of enterprise, etc.

Australia has a strong sheep cheese market but domestic production faces import competition.

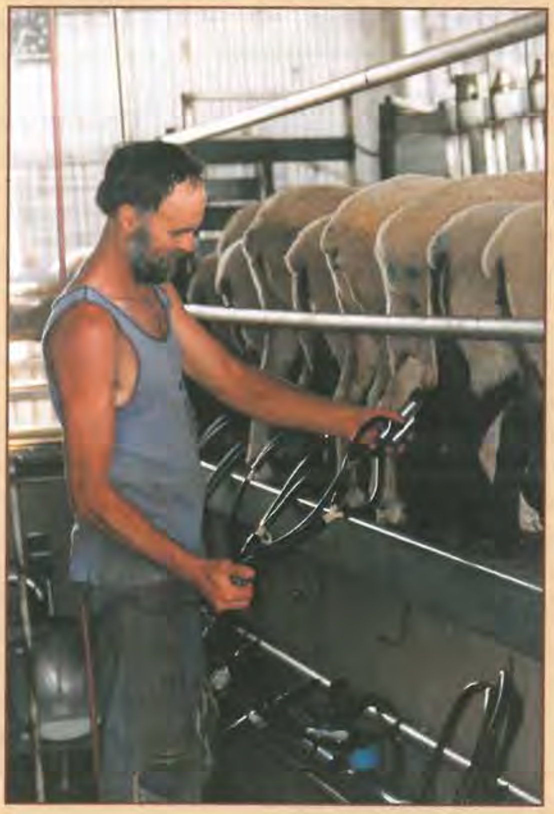
Cloverdene Dairy—a successful sheep-milking enterprise

Trevor Dennis was born at Karridale, near Margaret River, in the south-west of Western Australia, on 'Cloverdene' a traditional dairy farm. In 1963 his father decided to abandon dairying and started farming sheep for prime lamb production. Trevor inherited the family's farm and, together with his wife Debbie, began organic farming 11 years ago. In 1992 they started milking sheep.

Cloverdene dairy evolved from a desire to use value adding in conjunction with organic farming practices to produce a sought after product. It is an organic farm which targets the health food market: no chemicals are used in any stage of the production, and non animal rennet is used to produce the cheese. The closeness to Margaret River, a region frequented by tourists for its famous wines and cheeses, makes Cloverdene an ideal place to develop a vertically integrated, family owned sheep milking enterprise.

Under the trade name of Cloverdene, the Dennis family produces and commercialises natural and fruit flavoured yoghurt, fetta cheese, fromage (a semi-mature cheese), pecorino, baked ricotta and ghee. They have also developed a local market for young, milk fed lambs that are eagerly sought after by Perth restaurants.

They milk up to 150 sheep, mainly Poll Dorset × Merino and Border Leicester × Merino crosses in a 12/side herringbone parlour. Recently, they have purchased East Friesian genetics (the lambs were born in May 1997) with the aim to increasing their production while decreasing the number of sheep milked.



For a family enterprise already producing prime lambs, each ewe milked could generate an extra income of $80–150/year, assuming the ewes are local crossbred sheep, producing only 80–120 litres of milk per lactation. This extra income would rapidly offset establishment costs, so long as the family provides the labour.

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Water buffalo

Barry Lemcke

Introduction

Water buffalo (*Bubalus bubalis*) have been present in northern Australia since the 1820s. They have been used for many years for meat and hides. The buffalo industry is one of the oldest forms of land use of the Top End since European settlement.

A new domesticated industry has emerged following the destruction of much of the feral buffalo herd in Northern Australia in the 1980s for the control of brucellosis and tuberculosis. It is based on farmed stock, raised under good conditions, to supply a quality product for the restaurant trade. Research and development work began in the late 1980s and culminated in the registration of TenderBuff ® by the NT Buffalo Industry Council.

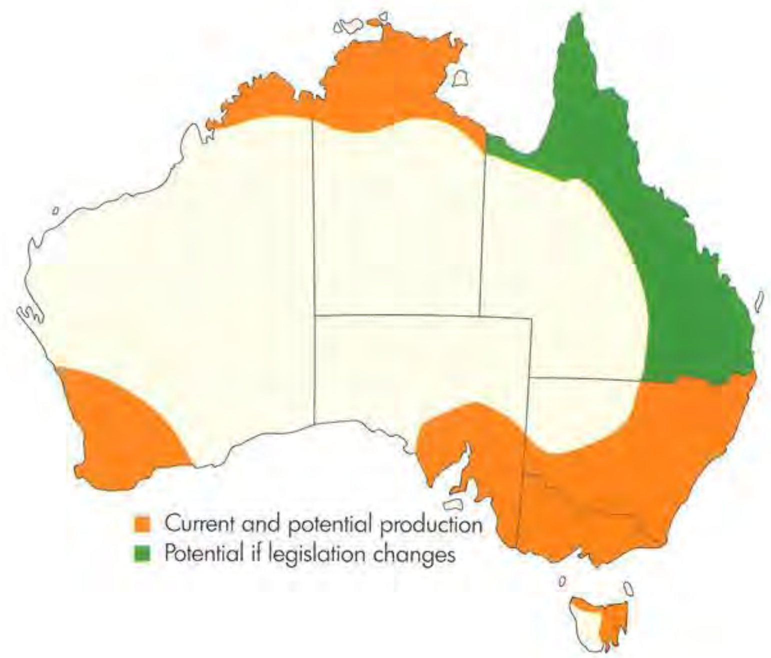
TenderBuff is a quality-assured and branded product, complying with a range of specifications, which allows customers to buy with confidence. The particular marketing strength of the product is the much lower fat and cholesterol percentages when compared with other meats, including beef. The cuts available are the same as beef with a similar range of tenderness amongst the various cuts. Flavour is slightly stronger than equivalent aged beef, but most consumers would not pick the difference.

Under temperate pasture conditions and good seasons, turnoff of TenderBuff at 14–18 months is possible compared with 24–30 months under normal NT improved pasture conditions.

Since 1996, crossbred riverine buffalo, using riverine bulls and some heifers from the USA, have been produced in small numbers. Australia currently has approximately 30–50,000 head of water buffalo of which some 20–30,000 remain feral in areas free of TB. Water buffalo are currently being farmed in all states except Queensland where current legislation does not permit them to be farmed or slaughtered. Permits are required in some states.

The world population of domesticated buffalo is around 140 million and mainly to be found in central and southern Asia, South-East Asia, and in increasing numbers in South America. Most are primarily used for milk or as draught animals and only slaughtered for meat at the end of their productive life.

Cattle farmers could easily adapt to the raising of water buffalo, since fencing and yard requirements are basically similar for both species.



Markets and marketing issues

There are several markets for buffalo. Breeders are sold locally in the NT and to southern states and are exported currently to East Malaysia (Sabah and Sarawak).

There are currently two markets for slaughter stock: the local TenderBuff markets in the NT and southern states, and potential markets overseas. For many years, bulls have been exported live to Brunei for direct slaughter. By-products are also marketed, the most common ones being hides, horns, meat meal and pet meat.

Current production of NT buffalo is: 1,000 head to Brunei; 200 head to TenderBuff; 500 head to export abattoirs.

The current market for buffalo meat is affected by a beef price slump which has caused cattle bull meat to be substituted for buffalo meat in southern markets. Until that slump, demand exceeded supplies in the NT industry. However, the base price of $3.10 per kg dressed to the producer has been maintained despite the cheapness of beef. This equates to a return of $650 per head for a 210 kg TenderBuff (less the abattoir kill fee of $55) which allows NT producers to establish improved-pasture grazing systems economically

Production in the States is small and in the rapid build-up phase for breeders.

Riverine buffalo or crosses may be more sought after than swamp buffalo in many SE Asian destinations in the future.

Production requirements

Water buffalo are adapted to a wide range of climatic conditions throughout Australia. They come from warm, humid, tropical areas but have been found to survive in the colder winter of temperate areas in Australia so long as adequate shelter-belts or shedding is available to protect them from the chill.

Water buffalo are also adapted to poorer pasture areas too wet or of marginal quality for cattle. They can forage in swampy conditions. They also eat a wider range of fodders than cattle and have been observed to clear irrigation channels of reeds and other growth not normally touched by cattle. They perform well on crop stubbles and by-products of grain or legumes.

Buffalo can be finished to TenderBuff specifications in a period of 60–80 days on a 30% grain/protein/roughage ration.

Selected bull from Coastal Plains Research Station (CPRS) selection herd in 1996 at 3 years old

About the author

Barry Lemcke has been working with buffalo since graduating in 1972 from the University of Sydney. He is the Principal Livestock Management Officer with the Pastoral Division of the Northern Territory Department of Primary Industry and Fisheries.

See *Key contacts* for address.

Key statistics

- Australia 30–50,000 head including 20–30,000 head feral
- World – 140 million
- Australian production 1000 head/annum to live export, 200 head for domestic market, 500 head for export meat.

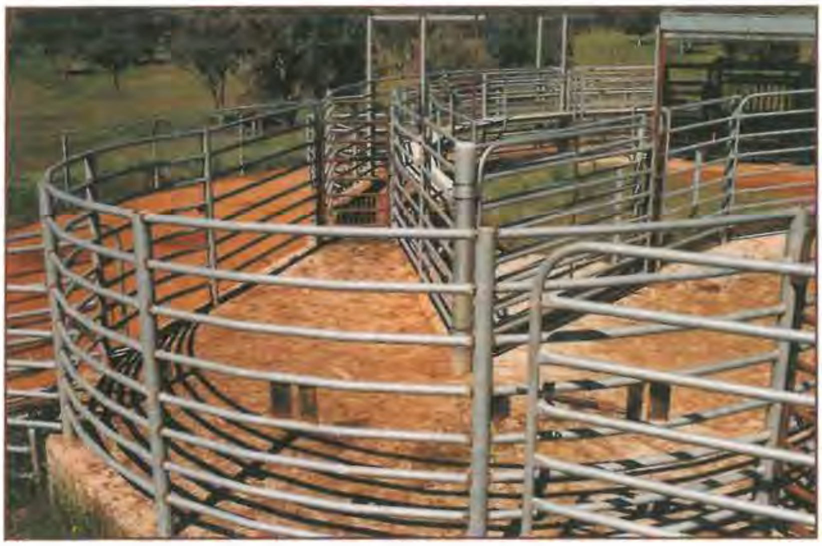
Breeds

Swamp buffalo. The 'tractor' of SE Asia was introduced to Australia in the 1820s to 1850s at various settlements on Melville Island and Cobourg Peninsula and escaped or were left behind when the settlements were abandoned. They colonised the northern coastline of the NT particularly the coastal flood plains which had good quality hymenachne pastures in abundance. They built up to approximately 350–400,000 head at their peak in the late 1970s. The disease eradication program reduced the population through turnoff and culling to around 40,000 head.

A ten-year selection program on swamp buffalo was carried out at Coastal Plains Research Station in the NT between 1986 and 1996 to improve growth rates/ fertility of the breed.

Riverine buffalo. In 1994, '95 and '97, riverine buffalo (the dairy breed from India/Pakistan) were imported from the USA. Pure-bred riverines were also imported from Italy and Bulgaria into Victoria for dairying and the production of mozzarella cheese.

The Riverine buffalo is a larger, 'beefier' animal than the swamp buffalo and, when crossed, produces a very fast-growing animal that produces high-quality meat. Up to 40% improvement in growth rate has been measured in the NT with the first-cross calves and yearlings. The first crossbreds slaughtered provided a TenderBuff product superior to that previously produced.



Yards of circular design tend to work best with buffalo

Animal husbandry

Buffalo are very similar to cattle in their husbandry and equipment requirements but when working with them, handlers will need to be aware of some subtle differences

Buffalo should be worked quietly and firmly and with less confrontation. When in close contact, buffalo will tend to stand up and face people or dogs rather than try to retreat and avoid them. They do become very docile when handled carefully but can also become cranky if handled roughly. They should be given time to adjust to new surroundings and will usually comply favourably.

As they have fewer sweat glands, buffalo can overheat more quickly than cattle if they are over-stressed, run for long distances in hot weather or are mustered during the heat of the day. They will wallow to reduce heat stress if water is available. They do the same to escape from insects such as buffalo flies.

Buffalo show more intelligence in the yards than cattle and appear to have a better memory of past events.

You will need to aim to work with smaller mobs than is possible with cattle. Normal yard management with buffalo – drafting, vaccinating, pregnancy testing, weighing etc – tends to take a little longer per head than with cattle, so you should reduce the numbers for a given work-space. Buffalo tend to work through the yards better if numbers are kept low and they are not worked in large, tight mobs. It is better to split a small group off the side of a larger mob, and work them through, then come for the next group. Circular designs tend to work best with buffalo, so that there are no corners where they can get bottled up.

Buffalo should be provided with good shade and shelter from heat in summer and cold in winter by using effective shelter-belts of trees or shade structures.

Some tree-trunk protection may be necessary so that buffalo do not eat or rub against the trunks. Where bark is being eaten, salt/mineral blocks can be used to reduce this craving. Increasing available fibre and roughage should also help. Feedlotting is also possible with 30% grain being a optimum grain content of the ration.

Naturally polled buffalo are not known in the NT. There are numerous advantages in dehorning, except where trophy hunting or excessive dog/dingo problems are encountered. These include less damage to fences, yards and people and less bruising when the animals are being transported, since without horns they take up less room. Buffalo can be dehorned as calves, using a hot iron before two weeks of age or using cup or scoop dehorners before four months. Adult animals can be tipped only – maximum of 1/3 of horn removed – as bleeding can be profuse if the horn is taken off closer to the head. Cauterising blood vessels with a hot iron is recommended. As with cattle, a ring of skin (hair) around the horn butt must be removed to ensure no horn regrowth in young calves. Cup dehorners can be successfully used between one and four months of age. Dehorning is not recommended any later than four months. Some social problems of dominance occur when horned and dehorned mature cows are mixed, so *all* should be dehorned at birth if the practice is adopted.

Buffalo have an oestrus of 21 days like cattle; however, gestation averages 325 days (10 1/2 months). In cold climates it is wise to avoid matings which will cause calving between April and September.

Buffalo will wallow anywhere where a puddle will form, particularly near a leaking trough or pipeline. They can survive quite readily without access to a wallow, as in the dry season in the NT.

Electric fencing is recommended as the most effective barrier. Buffalo tend to be a little harder to keep behind fences than cattle when feed becomes scarce.

Pasture and feed requirements are similar to cattle except that buffalo are better able to use low-quality roughage than cattle. In temperate winter climates, hay may be necessary when pastures are very short and green and highly digestible.

Dogs should not be used with buffalo, particularly when calves are present, as buffalo can be fiercely protective of their young.

TenderBuff males on improved tropical pastures in the 'wet' season at CPRS

Pest and disease control

In a given area, buffalo should be treated for the same diseases as cattle. This includes:

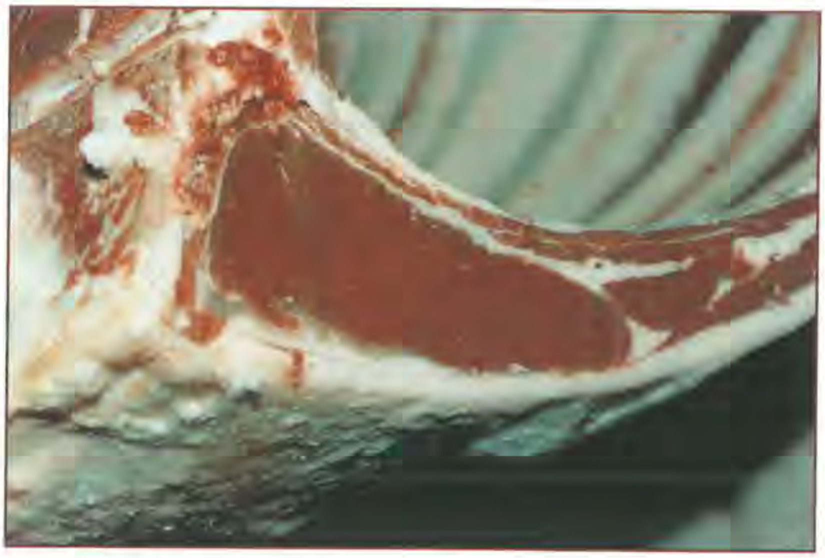
- 5 in 1 or 7 in 1 vaccinations;
- botulism vaccination; and
- worm control (Osteragia has been found a problem if untreated in some parts of WA).

It appears that buffalo are very susceptible under southern conditions to malignant catarrhal fever which can be fatal, so it is recommended that they do not have direct contact with sheep in the same paddocks. This appears to be a greater problem when the buffalo are stressed heavily, are in poor condition and arrive on a new property during a very cold period. Sheep are usually carriers of this disease and often are not affected.

There have been some reports of deaths from ostertagiasis. Owners should be aware of this and monitor worm-egg levels and tactically drench until a strategic drenching program is established for each region. Newly introduced buffalo from the NT would probably have little immunity to this worm. Again they would be more susceptible when in poor condition and under stress.

Buffalo lice (*Haematopinus tuberculatus*) are common in northern Australia and need to be controlled, particularly if stock get poor in condition. Small calves can build up high numbers and control will be necessary. Lice eggs are readily visible, attached to the bristles of a buffalo's coat, if numbers are high. Cattle lice treatments are usually effective and are best carried out 14–18 days apart to ensure the life cycle is completely broken – all buffalo on the property should be treated at the same time. Chlorpyrifos-based lice treatments should be avoided as they have been found toxic to some buffalo.

Buffalo do not usually carry cattle ticks except under exceptionally stressful conditions. They are not a normal host.



Lot fed TenderBuff product. This would be maximum permissible fat-still very little fat in the muscle. Forequarter cut between 11 – 12 rib exposing the porterhouse.

Buffalo flies (*Haematobia irritans exigua*) are present in the NT and Qld and are expanding their range slowly. Buffalo treated just before departure should not introduce the buffalo fly to other States. Sprays, pour-ons and spot treatments are all useful in the control of this fly which breeds in the dung. Numerous chemicals are available of varying effectiveness and price.

Back rubbers may be useful but buffalo can test many standard cattle installations. Trial and error is needed to find a suitable design for the area. A very solid post (concrete or hardwood) makes a good start.

Processing

TenderBuff animals are generally slaughtered at local abattoirs with a service-kill facility and access to an electrical stimulator. The animals require careful and stress-free handling as pH of the muscle post-slaughter is one of the criteria for full compliance with specifications.

For high quality markets it is imperative that the animal is young—less than 2 1/2 years of age with no permanent teeth – has more than 3 mm of fat over the p8 (rump) site and is between 150 and 220 kg dressed weight. Pre-slaughter conditions should be such that there is no stress involved in handling and transport or in the abattoir yards.

At slaughter, the carcase should be electrically stimulated to reduce the effects of chiller induced shrinkage of muscle. Preferably the cuts are vacuum packed or Cryovac® packed for a minimum of two weeks before sale. The pH of the meat before vacuum packaging should be less than 5.8 for a good tender product. TenderBuff ® is a quality assurance product which meets all of the above specifications and is a registered trade mark belonging to the Buffalo Industry Council of the NT.

TenderBuff specifications, when met, allow that carcase to have a strip brand applied (similar to the 'Lamb' brand). This is in use in the NT and also in Victoria with the permission of the NT Buffalo Industry Council. The brand is used in conjunction with a grid pricing system which discounts any carcases that fail the specs from the nominated premium price for that region or butcher involved.

When supplying the Brunei market, slaughter stock are treated with pour-on acaricide before shipping while breeder stock must comply with the long list of tests required by the importing country.

Economics

Costs and profits are very difficult to estimate for all areas because of the varying capital costs for land and equipment throughout Australia. They will not be significantly different to cattle costs in any given area. Gross margin costs for cattle can have the TenderBuff premium price negotiated for a particular area substituted into cattle data for the area as a good first approximation.

Recent prices are: TenderBuff – $3.10 per kg dressed weight (Darwin local market) and breeders NT $450–$600 per head.

Live export slaughter to Brunei: $1.45 per kg delivered to Darwin Wharf with Bayticol® treatment.

Young Riverine bulls or heifers from the USA cost $16,000 each delivered to Darwin.

Larger numbers of breeders are available from buffalo producers in the NT and smaller numbers from other states. $450–$600 can

Buffalo down south—Lake Hume Buffalo

Trevor and Sue Hall commenced water buffalo farming 3 ½ years ago on their 250 ha property on the Victorian shores of Lake Hume near Albury–Wodonga. Thirty ex-Northern Territory breeders were purchased in South Australia as a diversification option to beef cattle.

They found that the water buffalo fitted very well into their mainstream farming operation, with few extra requirements. Electric fencing had to be installed and sheds or tree shelter belts were needed to protect the buffalo from the cold. One of the main requirements was purpose-built yards in which to handle the buffalo. After much research and hard work, yards were constructed which allow Trevor to efficiently work the buffalo on his own without stress to the animals or danger to himself. All the animals are now 'paddock pattable' and conditioned for slaughter, a must for a prime quality carcass. Currently they have 100 buffalo on their property.

Little or no relevant information on farming water buffalo in colder climates was available when Sue and Trevor started buffalo farming, and losses occurred. They went through a very steep, trial-and-error learning curve. They are certain that 7 in 1 vaccinations are a must for their area. One of thehardest education jobs has been with local abattoirs and getting animals killed correctly to meet QA specifications.

Sue has been busy in the marketing area and they are currently marketing meat and smallgoods through Peters and Sons Butchery in Lavington, renowned in the Albury area for the quality of its products and creativity with smallgoods such as pastrami, salami, sausages, etc.

As numbers of animals in NSW and Victoria build up, other outlets will be required, and Sue is hopeful that buffalo farmers Australia wide will get together co-operatively to supply into the lucrative South-East Asian markets.

Eventually, Sue and Trevor hope to introduce Riverine genes into their herd to make it more productive, although they are currently very happy with the performance of their pure swamp buffalo herd. In 1995, they joined a consortium of farmers to purchase a swamp buffalo bull from the NT Department of Primary Industries and Fisheries, and the progeny of this bull are very promising.

Trevor and Sue are very optimistic about their new enterprise, particularly as they have been able to get into the industry on the ground floor. They believe buffalo has an excellent future as a niche market, low cholesterol meat.

purchase NT breeders with approximately $200 freight to southern states. The transport window recommended for the southern journey is between September and February for best adaptation to the cooler environment. Buffalo should not be mixed with sheep because of their susceptibility to Malignant Catarrhal Fever (MCF).

The gross margin for a TenderBuff finishing enterprise in the Darwin area for a 1,000 hectare improved pasture area is estimated to be currently around $130 per hectare.

The main attraction of buffalo farming is that it is a possible diversification for the cattle owner, in a market that may not be subject to price fluctuations as badly as beef, particularly in the build-up phase of herds which is occurring Australia-wide.

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Key references

Ross-Cockrill, W. (ed.) 1974 *The Husbandry and Health of the Domestic Buffalo* FAO of UN

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Aquaculture

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Abalone

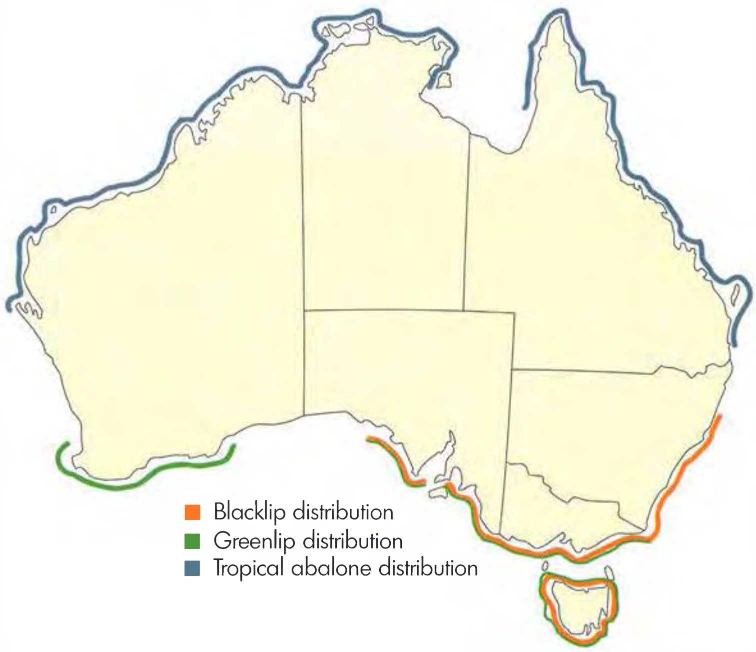
Patrick Hone
Ann Fleming

Introduction

Abalone are slow-growing herbivorous marine snails. There are over 100 species worldwide in the same genus, *Haliotis*, of which less than 10% are commercially important. They are found from the intertidal to the depth limit of marine plants (approximately 80–100 m), from tropical to cold waters. Aquaculture of abalone began in Australia about 16 years ago in Port Lincoln, South Australia and in Tasmania, through research into spawning blacklip and greenlip abalone. In contrast, abalone aquaculture is over 50 years old in Japan. The impetus for developing abalone aquaculture in Asian countries, and later in the USA, Mexico and South Africa has been the decline in their wild harvest fisheries because of over-exploitation. Australia has been fortunate that fisheries management has controlled the level of commercial abalone harvest at sustainable levels. Even so, Australia's abalone catch has declined from 8000 t in 1971–/72 to 5200 t in 1995–96.

Abalone are high price species that are grown intensively in both sea and land-based systems. Importantly, the trend in abalone culture has matched that world-wide for other aquaculture species in that successful culture in highly developed countries is dependent on total control over the grow-out conditions. The vagaries of climatic extremes that are experienced in the marine environment result in variable commercial viability with higher risk. The trend is to develop land-based systems that permit total control over growing systems. Seawater may be derived from shore-based pumping, artesian aquifers or by combining raw marine salt with inland freshwater sources. Aquifers have an added advantage in that temperature is often elevated and constant, but volumes may be low, and inland disposal of spent water is a problem.

Increases in world abalone prices in the last 15 years have made abalone aquaculture in Australia a more viable proposition. Australia supplies over 40% of the world's wild-harvested abalone, and its two main commercial species (blacklip and greenlip) have significant price margins over abalone species harvested from the tropics, subtropics, New Zealand, Chile and Europe. In 1994–95 prices for Australian abalone reached record levels of $38–45/kg (whole weight). Since then market price has steadied at $35–40/kg.



South Australia and Tasmania have led Australia's abalone aquaculture development in the past 10 years. There are currently 9 farms in South Australia and 12 in Tasmania, with development expenditures to date being $5.5m and $7.5m, respectively (Table 1). Both Victoria and Western Australia are in the early stages of introducing abalone aquaculture, with three new state-of-the-art shore-based facilities being developed in Victoria.

In the past 20 years, China and Taiwan have developed abalone aquaculture industries with annual production estimated at 500 and 1500 t, respectively. However, during this period both countries have continued to be net importers of abalone products, as their internal demand for product cannot be met by domestic production. China is reaching the limits of sites suitable for development. Further, typhoons frequently cause extensive damage to sites in China. Taiwan has continued to experience water quality problems that have plagued its prawn industry, and this is expected to restrict future development.

Most of the first business plans for abalone aquaculture in Australia used a figure of 4–5 years to reach a market size of 70–80 mm. The rapid industry acceptance of manufactured diets and improved tank technology over the last three years has seen this figure reduced to 3–4 years. This makes investment far less risky and provides for a faster return on investment. The development of hatcheries producing millions of juveniles has allowed new operators to establish grow-out operations without the need to develop a hatchery, further reducing the time for positive cash flow.

Abalone farming is much like intensive rearing of livestock, in particular pigs and poultry. The skills required involve a mixture of biology, engineering and innovation. Abalone farmers in Australia have come from professional, farming and fisheries backgrounds. Key staff, in particular those working in the hatchery phase of production, are usually aquaculture graduates.

Table 1. Abalone farms currently approved in each State (land-based, sea-based) and expected development depending on lease approvals, and abalone aquaculture production by State, with a guesstimate of production at the turn of the century (whole weight, production data courtesy of industry).

State	Aquaculture operations		Production (t)		
	Currently approved	Applications pending	1996–97	1997–98	2000–01
SA	8, 1	>30	5	20	>250
TAS	3, 9	>15	5	5	>150
Vic	3, 1	>10	0	0	>75
WA[a]	0	>10	0	0	>5
NSW[b]	0	2 (R&D)	0	0	>5
Qld	0	?	0	0	?
Total	**25**	**65**	**10**	**25**	**485**

[a] WA has developed aquaculture parks at Albany and Broome to facilitate development.
[b] NSW is evaluating the commercial viability of enhancing wild populations by releasing larvae and/or juvenile cultured abalone.

About the authors

Patrick Hone and Ann Fleming have been researching abalone aquaculture for the past 10 years. They have been responsible for the development of the national FRDC Abalone Aquaculture Sub-program (see *Key contacts* for address) and its integration with the CRC for Aquaculture's abalone projects. The focus of their work has been on abalone nutrition, system design for grow-out, and determining optimum conditions for growth.

Blacklip abalone

Greenlip abalone

Markets and marketing issues

It is important to differentiate the market for cultured abalone and the wild product. Wild product from Australia has limited markets as it is restricted by the minimum harvest size limits imposed on capture (120–145 mm). It is sold by weight. The aquacultured product, on the other hand, can be sold at any size. The world market for aquacultured abalone is primarily for live individuals in the size range 50–100 mm. Table 2 shows that the aquacultured product fetches a premium over wild product. The small quantities (Table 1) of cultured product that have been marketed domestically have usually fetched prices in the range $40–45/kg (live, whole weight) for 70–80 mm Australian product (Table 2). With a decline in wild-harvested abalone stocks and growing demand in Asia, prices will continue to rise for the next 20 years.

Almost all of Australia's abalone product is sold to Asian markets, with only a small amount being sold on the domestic market. For live product the farmer usually sells direct to a distributor in Hong Kong, Singapore or Japan. Canned or fresh-frozen product is sold to local abalone processors who then sell to wholesalers in Asia when the price and shipment volumes are right. Successful abalone farming will require good market knowledge. At present abalone farmers are using Australia's wild fishery market links. Value adding will be achieved in future with the development of specific aquaculture markets and labelling promoting the quality of the product.

Production requirements

Abalone require water of the same chemical composition as seawater (Table 3).

Siting of farms is one of the most important development decisions. The most important factors for siting land-based abalone farms are:

- access to marine quality water that has low daily and annual temperature variations, and averages the optimum temperature requirement for the species;
- freedom from pollution, in particular urban development run-off;
- low cost land;
- low head height for pumping water from either ocean or aquifer;

- access to environmentally approved methods for waste seawater disposal; and
- close to infrastructure and services, including three-phase power, airfreight terminal and trades people.

Existing land-based abalone farms are located on the coast in rural regions. In South Australia the main constraint has been finding sites close to three-phase power supply which have access to clean water supplies. Similarly, in other States access to sites is limited by coastal parks, electricity supplies, and isolation from services and infrastructure. The development of recirculated temperature-controlled systems (using less water) could see small abalone farms utilising inland aquifer saline water that has the added benefits of relatively constant temperature and of being pathogen free. However, coastal sites will be the preferred land-based sites.

Species

Abalone are marine snails belonging to the class Gastropoda of the phylum Mollusca. These are molluscs with single shells, or no shell at all, and which move by means of a broad muscular foot. Currently only two species of abalone are being farmed in Australia: greenlip (*Haliotis laevigata*) and blacklip (*H. rubra*). Greenlip is farmed in SA, Victoria and Tasmania, and blacklip in Victoria and Tasmania. Greenlip is preferred for culture because it has a faster growth rate (20–30 mm/year) than blacklip (15–25 mm/year) and a higher market price.

In Western Australia, Roes abalone shows promise, and its intertidal habitat means that it is tolerant of a broad range of culture conditions. The tropical abalone, *H. asinina*, has created interest because preliminary growth trials have shown it to be one of the fastest growing abalone (>40 mm/year) in the world. New ventures are proposed in Broome and Cairns using this species.

Farmers in SA, Victoria and Tasmania are interested in developing the hybrid between greenlip and blacklip abalone. There is evidence that this hybrid grows more rapidly and is easier to handle than its parents in certain grow-out designs. The 'tiger' colour variation of blacklip found in Victoria has potential as this form is similar in colour to the premium-priced Japanese species. Crossing the cold-water species *H. rubra* with *H. cyclobates*, is yielding individuals that may have a broader temperature tolerance.

Table 2. Price of different cultured abalone and wild product in relation to markets

Source	Type	Size[a]	Market	Price $US/kg[b]
Australia	wild, live	<300 g	Japan	35–37
Australia	wild, live	400 g	Japan	33–35
Australia	wild, live	350–500 g	Hong Kong	32–34
Australia	aquaculture, live	70–80 mm	Hong Kong	40–45
China	aquaculture, live	70–80 mm	Japan	45–48
China	aquaculture, live	40–60 mm	Hong Kong	42
China	aquaculture, live	60–85 mm	China	50–55
Japan	aquaculture, live	75–85 mm	Japan	52
Taiwan	aquaculture, live	50–65 mm	Japan	35

[a] A 60–90 mm greenlip weighs 35–90g.
[b] The price refers to the market price and not the beach price. It costs approximately A$5–10/kg (depending on quantity) to deliver product live to these markets.
Source: Mr Tony Johnston, Tasmanian Seafoods, August 1996, 3rd FRDC Abalone Aquaculture Workshop, Port Lincoln.

Table 3. Environmental requirements for temperate and tropical abalone (optimum values are in brackets).

Species	Temperature °C	Salinity mg/L	Oxygen % saturation	pH	Ammonia mg/L
Greenlip	12–22 (18)	34–37 (35)	80–100 (100)	8.0–8.4	0.0–0.03[1]
Blacklip	10–22 (16–18)	34–37 (35)	80–100 (100)	8.0–8.4	na
H. asinina	20–32 (28)	34–37 (35)	80–100 (100)	8.0–8.4	na

[1] Free ammonia-nitrogen (mg NH_3, Harris et al., University of Tasmania)

Fish husbandry

Farm types. There are two types of land-based abalone farms: hatchery based and grow-out only. The former method is vertically integrated, comprising three stages of production:

1. hatchery;
2. nursery; and
3. grow-out.

Hatchery-based farms are more technically difficult to operate, require greater capital costs and are riskier, as the production cycle is considerably longer. Conversely, the rate of return on hatchery-based farms is higher. In Australia, hatchery-based farms are more akin to industrial aquaculture that employ a large number of staff (>30) and plan to produce large quantities of product (> 200 t).

Grow-out only farms buy juvenile abalone (20–25 mm, 1 year old) from hatcheries and aim to grow abalone to production size in less than 2.5 years. The grow-out farm requires tank structures of only one type and the farmer's principal jobs are system maintenance, cleaning, feeding, stock grading and harvest. This farming method is more suitable for a family operated business with one or two staff.

Typical grow-out farm layout. A typical land-based grow-out farm starts with the seawater intake system. This must be capable of pumping upwards of 5–100 ML/day. An ideal site has a low head for pumping and low suspended solids in the water, reducing the need to filter or backwash. Most farms have a primary filter before the pumps, then sand filters after the pumps capable of filtering down to 10–20 microns nominal.

The best site has a low inclination away from the water source, which facilitates gravity drainage and the capability to cascade water from tank to tank. Water is delivered by a manifold to tanks set up in parallel. Water is collected at the end of tanks in a common sump that allows wastewater to be processed before returning to the sea or being recharged into the aquifer. Tanks are shallow, permitting use of low pressure/high volume air blowers. The delivery line for the air is usually a 100–300 mm PVC pipe. Reliability is crucial, so it is important that backups of all mechanical equipment exist and that spares are available. All farms must have monitoring systems that alert the farmers if systems fail, with most having automatic switching systems to activate backup equipment.

Table 4. Species of Australian abalone that are farmed or have potential for farming.

Common name	Species	Environment	Distribution
Greenlip	*H. laevigata*	12–22°C, high water movement, depth 5–40 m, exposed habitat for adults	Southern Australia, Tasmania
Blacklip	*H. rubra*	8–22°C, cryptic habitat, depth 1–20 m	Southern NSW to Great Australian Bight, Tasmania
Roei or Roes abalone	*H. roei*	12–24°C, intertidal to 3 m depth, cryptic	SW Western Australia to central SA
Tropical abalone	*H. asinina*	18–30°C,	Tropical reefs, Qld, NT and NW WA
Hybrids	Genetic cross between greenlip and blacklip	same as greenlip	Rare in wild
Tigers	Sub-species of blacklip that have distinctive striped foot	same as blacklip	Rare in wild where blacklip found, more common in Port Phillip Bay

Key messages

- high value export product
- product is a luxury niche item highly valued by Asian markets
- development requires rural sites, preferably with low pumping head on the coast
- technology is commercially available
- requires a high level of aquaculture farming skills
- development is supported by the FRDC Abalone Aquaculture Sub-Program

Production cycle. Broodstock are collected from the wild. Spawning time varies between location. For South Australia, blacklip are in spawning condition in winter and early spring while greenlip are in condition in spring and early summer. Greenlip in Tasmanian waters are in condition in late spring because rises in water temperature lag those in the northern waters. Abalone are cued to spawn primarily by changes in temperature. Male and female abalone are identified by gonad colour, which is green in females and pale yellow-grey in males. The broodstock are transported back to the hatchery and the sexes separated into tanks.

UV-light-irradiated seawater is used to induce spawning, which takes about 4–8 hours to complete. Males usually spawn first and will continue to eject sperm for several hours. Females spawn in pulses with eggs negatively buoyant and green/grey in colour. Eggs are siphoned, cleaned and fertilised with the right quantity of sperm (Fig. 1). A single female can produce several million eggs.

The eggs hatch, releasing larvae, approximately 24 hours later depending on water temperature. Larvae, which are free swimming and do not feed, pass through multiple development stages before they are ready to settle. Settlement occurs 4–10 days after fertilisation. Larvae ready to settle are transferred to tanks which have surfaces that have been preconditioned with microalgae. The microalgal biofilm on the surface is believed to induce the abalone to settle. The settlement period has the highest rate of mortality (Fig. 1), with survival being 5–20%, with the average towards the lower end of this range. Abalone feed on the microalgae (predominantly benthic diatoms) whose growth is managed by the farmer through control of light and nutrients. Abalone are removed when they are 5–10 mm and transferred to nursery tanks. A typical nursery tank holds 20,000–30,000 animals. Abalone are fed on a manufactured diet from this period on. Some farms still supplement with macroalgae, but the inconvenience and handling costs make this less economic. Feed is supplied at the rate of 1–3% of body weight depending on temperature. The feed-conversion ratio (ratio of feed intake to meat gain) ranges from 1.3–1.5 and feed presently costs approximately $2500/t.

Once abalone reach 20–25 mm they are transferred to grow-out tanks. Tank water turnover ranges from every 2 hours to 30 minutes. Aeration is supplied to tanks as a backup if the water stops. Aeration also assists in removing faecal material by keeping it in suspension.

Table 5. Summary of farm types (hatchery and grow-out) showing the size of abalone at each production stage, and some important production parameters for each stage (for temperate abalone).

	Hatchery	Nursery	Grow-out
Production time	4–10 days	8–12 months	2–3 years
Water requirements[a]	low <10 kL/day	Medium, 0.1–1 ML/day	High, 5–100 ML/day
Feed	None	Microalgae, then weaned onto manufactured diet	Manufactured diets +/or algae
Growth rate greenlip[c]		30–40 [b] to 80 µm/day	40–140 µm/day
Growth rate blacklip[c]		30–40 [b] to 60 µm/day	30–100 µm/day
Farm type (size of abalone for each stage of production)			
Hatchery (integrated)	larvae	300 µm — 20/25 mm	20/25– 60/80 mm
Grow-out (only)			20/25– 60/80 mm

[a] Depends on numbers of abalone being farmed.
[b] Growth rate while still on microalgal diet (5–10 mm size class).
[c] Growth rate data are for increase in shell length; the growth rates are minimum and maximum range corresponding with seasonal variation for the grow-out stage.

Figure 1. Survival rate for each stage of production development.

Hatchery stage				Nursery stage		Grow-out	
eggs →	fertilisation →	larvae →	settlement →	150 days →	1st year →	2nd year →	3-4 year
	80-85%	80%	50%	5-20%	80-90%	90-95%	90-95%

Abalone remain in the grow-out tanks from 2–3 years. They may be graded once or twice during this period, but the aim is to minimise handling.

Pests and disease control

Abalone farming in Australia and overseas has been relatively free of pests and diseases.

Two main pests have caused some problems in Australia. Sea-based farms have had problems with the polychaete, *Polydora* sp. The common name is mudworm. It affects the abalone by boring into the shell which the abalone repairs by forming a blister over the worm cavity. The mudworm do not consume the abalone tissue, but infected abalone are weakened and more susceptible to stress. If the infection continues the result can be a mortality rate of over 60% in sea-based farms. Land-based abalone farms have had few mudworm infections. Farmers manage this by removing infected stock. Farmers have found when abalone are kept in fast-growing conditions with good water flow they can overcome the infection and eradicate the mudworm.

Perkinsus olseni, a protozoan parasite, occurs in two main locations in Southern Australian waters. *Perkinsus* results in pustules within the foot muscle and, in severe cases, causes death. There is no known chemical treatment for the condition. The only known management method is to reduce the water temperature. If infected abalone are grown for over 6 months in waters kept at 12°C, the abalone can overcome the infection. This solution is not feasible for land-based farms that may have annual water exchanges of 5–100 ML/day. The only way *Perkinsus* can enter farms is from wild stock. It is therefore essential that farmers inspect all broodstock collected from the wild and keep them isolated from cultured stock. In South Australia, farmers take care not to collect broodstock from areas known to be infected with *Perkinsus.*

Harvest and handling

Abalone aquaculture product is sold either live, fresh frozen or for canning. The first usually involves direct sale to wholesalers in Asia, the other two methods involve selling to local abalone processors.

Preparation for live harvesting of abalone commences with cessation of feeding several days before shipment. It is important that the gut is empty at harvest. Abalone are harvested using a spatula that is quickly pushed under the foot. This is done in either the early morning or late afternoon to reduce temperature stress. Some farmers have tried using warm seawater to encourage abalone to drop off the tank's surface, but this method increases stress. No chemicals are allowed during harvesting.

Abalone are usually harvested from their tanks the day before shipment and placed in a holding tank with good water exchange. This is done to identify and remove any abalone that may die as a result of being cut during harvesting. Abalone do not have a blood clotting agent so any cut is potentially lethal. It also makes it easier to pack the abalone on the shipment day as harvesting may take several hours the day before. Abalone are packed in foam containers (airline approved) inside plastic bags. Within the plastic bag a damp cloth is placed but no water, as excess water will kill abalone during transport. The plastic bag is filled with approximately 20–30% medical grade oxygen and sealed. This bag is placed inside another bag and that bag sealed. Oxygen is required only for transport periods greater than 12 hours. A further refinement is to pack abalone in pairs foot to foot and wrap in damp cloth. This is done only for larger abalone.

Tas Univalve's abalone growing tanks at Swansea.

It is important to test shipping methods without product to ensure that the foam containers will arrive on time according to the air schedule chosen.

Fresh-frozen and canned product can be harvested on site and placed immediately into an ice slurry that results in death while maintaining tissue quality. Product is then delivered immediately to processors.

Economics of production

Abalone farming is a medium-to-high-risk venture. The reasons are:

1. a single system failure will kill a high proportion of the stock (large abalone die first) which are dependent on water and aeration for survival;
2. the development cycle in Australia has only just completed pilot-scale production;
3. the full production cycle takes over 3 years;
4. the break-even period for pay back has been estimated to be between 8–9 years; and
5. while several farms are selling product, a complete economic analysis of their production costs will not be available until the end of the pay-back period.

Because abalone farming is relatively new, and farms are being developed in a variety of ways, no single analysis would cover the economic situation. Most farms (hatchery based) being developed are quite large, requiring investment of several million dollars. Owners are protective of their business plans.

The development of grow-out only farms has just commenced, with the guarantee of seed supply from the hatcheries. This type of farming will be more suited to smaller investors.

The economic outlook remains positive. Importantly, most business plans were developed in the late 80s early 90s for the current Australian farms and based their internal rate of return on a price of between $25–30/kg. Since then, the price has increased and the cost of production has declined because of improved grow-out systems and faster growth rates. Further, hatcheries are developing new markets for their product with the development of grow-out only farms and the demand for larvae and seed for stock enhancement of wild fisheries. Farms are now selling juveniles (10–20 mm) for between 2–10¢/mm depending on volume and larvae for $1000/million.

Key contacts

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Barramundi

Chris Barlow

Introduction

Barramundi (*Lates calcarifer)* farming in Australia started in the mid-1980s in north Queensland. The industry has grown rapidly, and although the bulk of the production still comes from north Queensland, the fish is now farmed in all mainland States except Victoria. Barramundi is also farmed in many countries in South-east Asia, where it is known as sea bass.

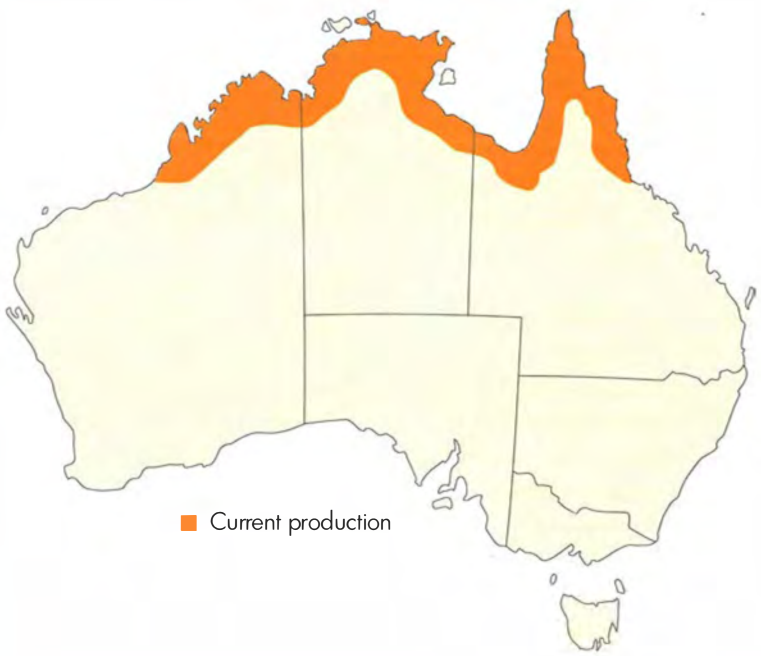
Barramundi has many attributes which makes it an excellent species for aquaculture. Broodstock can be spawned easily (all year round under controlled conditions) and they produce many offspring. Fingerling production is reasonably straightforward. They can be raised intensively indoors, or in extensive outdoor ponds. The species is easily weaned onto pelleted diets and grows very quickly. It is a hardy fish and adapts well to crowding. It can be grown in fresh and salt water, so it can be farmed on the coast or inland. Barramundi also adapts well to indoor, environmentally controlled recirculating water systems. It is a sought-after table fish and commands a premium price in the market.

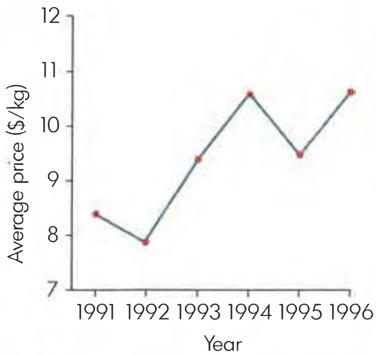
About 460 t of farmed barramundi was produced in Australia in 1995–96, valued at about $5m. The knowledge base and facilities of the current producers could support a two- to four-fold increase in production.

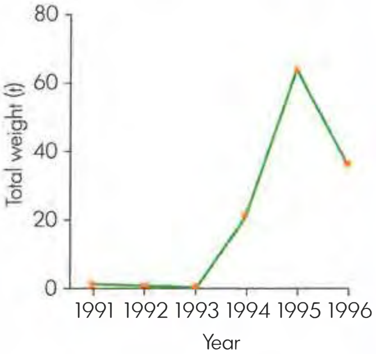
Barramundi farmers have come from all walks of life, although most are from a farming background. The successful ones share several personal attributes, such as the ability to learn new skills associated with fish husbandry and marketing, a commitment to building a new business in the face of early difficulties and unprofitable periods, a willingness to take financial risks, and adequate capital to support the initial establishment phase.

Marketing issues

Most farmed barramundi (ca 70%) is marketed as plate-size product, ie. 350–500 g. The remainder is sold as large (> 2 kg) fish. Prices at the point-of-first-sale in 1995–97 generally ranged from $9.50–11.50/kg. Most product is sold by direct consignment to wholesalers in Sydney and Melbourne, although smaller producers tend to trade via the auction floor. There is also a small trade in live fish, generally supplied by the producers in southern Australia.







Average price ($/kg) and total weight (t) of whole, farmed barramundi auctioned at the Sydney Fish market from 1991 to 1996. Fish sold at auction represent only a small portion of total production.

A premium is paid for the Australian product, even though Australian wholesalers can import fresh, chilled barramundi from south-east Asia, often at prices below the cost of production in Australia. Although the exact quantity is not known, the amount imported is probably more than that farmed in Australia.

The key constraint to future expansion is the ability of the industry to develop the domestic market and identify profitable overseas markets. Increasing the production of plate-sized barramundi to more than 500 t/year, without extensive promotion, will result in a fall in the price paid by Australian wholesalers. The Australian Barramundi Farmers Association (ABFA) is currently conducting a marketing campaign so that the anticipated production increase will meet a ready market.

In the longer term the industry is looking at product diversification and market opportunities overseas. It is envisaged that the diversification will include fillets from larger fish (up to 3 kg), for which there is a large domestic market, and the production of barramundi cutlets for sale in supermarket chains. In addition, product diversification will pave the way for export development.

Production requirements

There are three quite different methods currently used for growing fingerlings to market size. The most common grow-out system is cage culture in purpose-built freshwater ponds. Another method is cage culture in estuarine waters, although relatively few companies are doing this at the present time. The third system is intensive production indoors, in controlled-environment buildings, using underground (ie. pathogen-free) water and a high level of recirculation through biological filters.

Barramundi require warm (tropical) temperatures to sustain commercial growth rates. For this reason, farming in ponds and estuaries should be undertaken only in areas where the water temperature in winter remains above 20°C. In coastal regions this means areas north of Townsville (see map). Barramundi can live at temperatures as low as 16°C, but growth virtually ceases and the immune system is depressed, making the fish very susceptible to disease.

The controlled-environment systems can be operated anywhere in the country. The capital and operating costs for these facilities are usually greater than for the equivalent level of production in outdoor cage

About the author

Chris Barlow (BSc, MSc) has been conducting research into the aquaculture of freshwater fishes and crustaceans for over 20 years. He has worked in Malaysia, the Philippines, New South Wales and Queensland. He has been working on barramundi aquaculture since the mid-1980s, initially on nursery rearing and grow-out husbandry, and more recently on nutrition. He is currently in charge of QDPI's aquaculture research and development activities in north Queensland. Contact address: Queensland Department of Primary Industries, Freshwater Fisheries and Aquaculture Centre, Walkamin, Qld, 4872. Phone: (070) 933 733.

operations. However, they can be located close to markets, thus defraying costs associated with transporting product to market.

Other factors to consider when assessing the suitability of a site for barramundi farming include:

- an abundant supply of high-quality water;
- for pond systems, impermeable soils on a gently sloping terrain;
- proximity to essential services and infrastructure such as a work force, technical and veterinary expertise, support industries (feed manufacturers, hardware, mechanical, electricity) and processing facilities;
- ability to secure the site against poachers and predators;
- future adjacent developments that may have environmental impacts affecting fish health;
- proximity to local and domestic markets; and
- proximity to a major airport.

As with other forms of aquaculture, a range of government permits is required for farming barramundi.

Varieties

There has been no selective breeding of barramundi. To implement such a program would be difficult because of the logistics associated with maintaining adequate numbers of family lines through generations.

Fish husbandry

There are three distinct phases to barramundi aquaculture: the hatchery phase, involving broodstock maintenance and larval rearing; nursery rearing; and grow-out. Salt water is essential for broodstock maturation and larval rearing, while the nursery and grow-out phases can be conducted in either salt or fresh water.

The hatchery component of barramundi farming is very specialised, as it requires dedicated and expensive facilities, access to salt water, preferably saltwater ponds for larval rearing, and a considerable degree of technical skill. Broodstock can be kept in spawning condition year-round if housed in environmentally controlled tanks, with temperature and photoperiod emulating the natural spawning season. Spawning requires the injection of reproductive hormones.

Aerial view of an estuarine-based barramundi farm

Key statistics

Production and value of farmed barramundi.

Year	Production (t)	Value ($m)
1989–90	37	0.43
1990–91	105	1.12
1991–92	162	1.64
1992–93	252	2.52
1993–94	338	3.34
1994–95	355	3.83
1995–96	464	5.00

Fertilised eggs are collected from the spawning tanks and transferred to incubators. Hatching takes about 14–17 hours, and larvae commence feeding 1–2 days after hatching. Larval rearing is conducted intensively in hatcheries, or extensively in fertilised saltwater ponds. Larvae change to juvenile fish at 11–12 mm total length, which corresponds to about 12–20 days after hatching, depending on food supply and water temperature during the larval phase.

Some hatcheries do not maintain broodstock, but buy fertilised eggs from other hatcheries, which are then reared to fingerlings. The majority of farmers, however, neither maintain broodstock nor operate hatcheries, preferring to source their stock as fingerlings from the few large farms with hatcheries. Fingerlings are generally sold at between 25 and 45 mm total length. Larger fingerlings are more expensive but easier to rear.

Fingerlings are maintained in nursery facilities until approximately 80 mm total length. Nursery facilities are small fibreglass tanks or fine-mesh cages (about 1 m^3) floating in larger tanks. Weaning of fingerlings from natural live food organisms to manufactured diets is conducted in the nursery. Cannibalism can be a major cause of mortality during the nursery phase. To prevent this, the fish are size graded regularly.

Fish are transferred to grow-out cages when they are over about 80 mm total length. Cages are made from knotless mesh netting, and vary in size from 4–50 m^2 surface area and 2–4 m deep. Biofouling can reduce the size of the mesh openings and thus restrict the flow of water through the cages, leading to poor water quality. Consequently, the mesh must be changed and cleaned regularly.

Stocking densities of between 15 and 40 kg/m^3 are most common, but higher densities are used on some farms. Barramundi are fed on commercially available pelleted diets. Fish are fed up to 6 times/day when first weaned. The frequency of feeding is reduced progressively to once per day when the fish weigh more than about 100 g. Semi-floating pellets, rather than sinking pellets, are now widely used because they are available to the fish for a longer time and feeding activity is more easily observed.

Water quality parameters such as dissolved oxygen, pH, temperature and light penetration need to be monitored frequently. Aerators are used to maintain dissolved oxygen levels at greater than 5 ppm. Water exchange rates vary depending on the intensity of production, but generally about 5–10% of the pond water is exchanged daily.

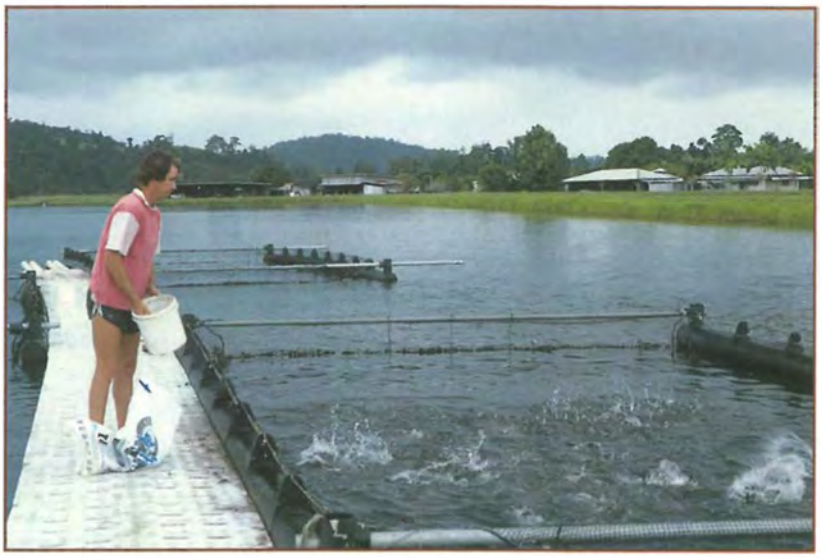
Key messages

- biological attributes excellent for aquaculture
- tropical species, but can be farmed in indoor systems in temperate areas
- fresh and salt water production
- markets need developing

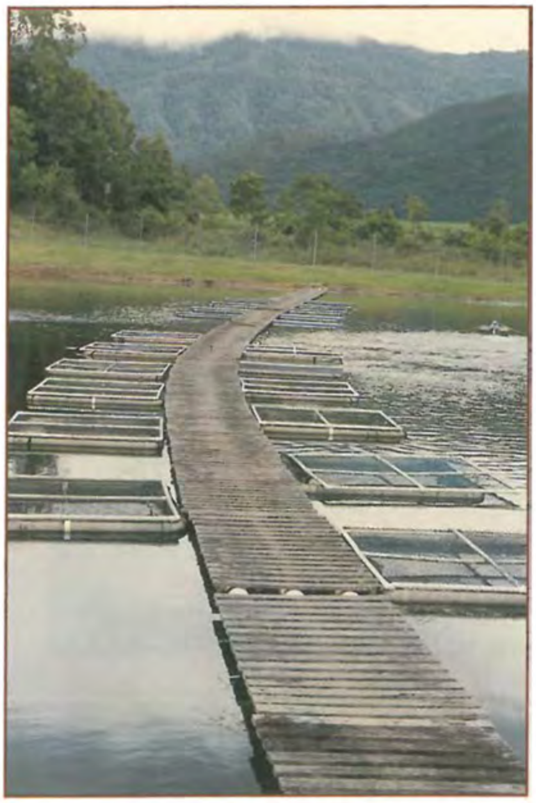
Provided good husbandry is practised, and fingerlings are supplied at the beginning of the growing season (late Oct–early Nov), marketable, plate-size fish will be attained in 6–8 months. Growing fish to 2–3 kg may take 2–2.5 years.

Disease control

Like all other cultured animals, barramundi is subject to a range of bacterial, fungal, viral and parasitic diseases. Disease outbreaks are usually associated with some form of stress, such as, for instance, extremes of temperature, low dissolved oxygen, poor nutrition or handling of the fish. Stress can be reduced by ensuring water quality remains near optimal levels, by reducing densities (to a practical yet economic level), and by feeding high quality diets. Watching for signals such as appetite depression, irregular swimming patterns, increased frequency of gill movement and any general irregularities facilitates rapid diagnosis, enabling early treatment and reduced mortality.



Feeding barramundi held in cages in a freshwater pond



Grow-out cages in a freshwater pond on a barramundi farm in northern Queensland

Bacterial infection is by far the most common cause of disease in barramundi aquaculture. Columnaris disease is particularly common in small fingerlings held in water below about 25°C. Other bacterial diseases are seen throughout the year but generally become more prevalent in mid-winter and mid-summer. Another factor that is often associated with bacterial disease is frequent grading. Once fingerlings are moved from nursery tanks to grow-out cages and grading frequency declines, disease incidence also declines. Bacteria have numerous points of infection, but damaged skins in badly affected fish seem to be common.

Fungal infections are most prevalent in cold waters (less than about 22°C), and are equally common in fish reared in fresh and salt water. Fungal infections appear as white blotches on the skin, and usually follow skin damage resulting from handling.

Two viral diseases have been reported in barramundi in Australia. Both are of relatively minor significance in terms of affecting production, and are easily prevented by maintaining hygienic conditions in hatcheries and grow-out environments.

Small numbers of parasites are often found in farmed barramundi. Disease outbreaks are relatively uncommon, but when they do occur rapid diagnosis and treatment are necessary to avoid large losses. The most commonly encountered parasitic disease is white spot in broodstock held in salt water. White spot is caused by the protozoan *Cryptocaryon irritans*, and is controlled by bathing the fish in fresh water for several days.

The major pest problem in fresh water is water rats. These are controlled by trapping and relocating. Predatory birds, such as cormorants, are not a serious problem in barramundi farming in fresh waters, because fish are usually held in cages or tanks which the birds cannot access. On marine farms, considerable losses can occur as a result of predators (eg., sharks, crocodiles, dolphins, puffer fish) making holes in nets, thus allowing fish to escape. To exclude such predators, marine farms have heavy-meshed predator nets suspended around the perimeter of the farm.

Harvesting, processing and packaging

As most farmed barramundi are produced in cages, harvesting is relatively simple. It is only a matter of gathering up a corner of the net to concentrate the fish, and scooping them out with nets. Handling nets should be made of a soft knotless mesh, to reduce any physical damage associated with extracting fish from the cages.

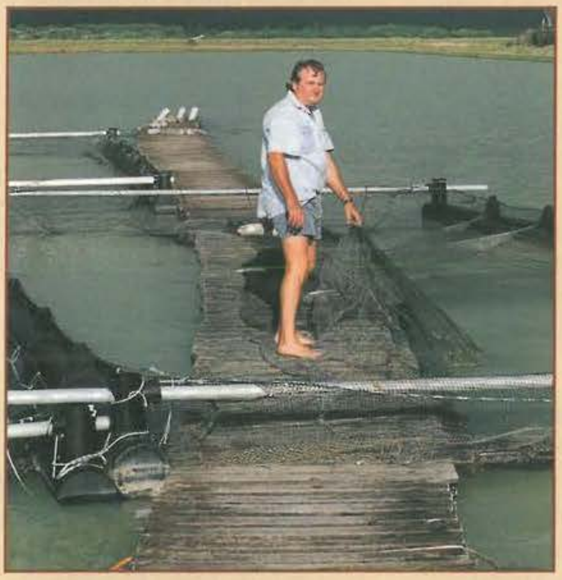
After harvesting from the cages, the fish are euthanased by immersion in an ice slurry. They are then graded according to size and packed in plastic bags in styrofoam boxes for transport. The great majority of fish are now sold guts-in; processing takes place at the wholesale or retail points in the marketing chain. Farms have processing and packaging facilities either on site or close by. Department of Health approval is required for processing facilities.

Cris Phillips boosts the barramundi bonanza

In 1986, Cris Phillips was an Innisfail sugarcane farmer and a keen angler who liked to go fishing. He was aware of the advances being made in farming barramundi in South East Asia and believed in the potential of aquaculture in Australia.

In 1997, Cris is still a cane farmer but rarely gets the opportunity to go fishing in the ocean, because he is now too busy looking after ponds full of barramundi. He has pioneered the development of one of Australia's largest barramundi farms.

Cris began fish farming in 1987, producing 11 t of plate-size barramundi. With experience and expansion he increased his production to 25 t in 1991. A personal milestone was achieved in 1992 when production exceeded 50 t, and economic viability became a reality at last. Farm output has continued to increase with the relocation to a new farm site. In 1996–97 he produced 138 t of barramundi.



Factors contributing to this rapid growth included the development of reliable spawning techniques and the subsequent production of barramundi fingerlings at lower cost through pond-based larval rearing procedures. Reliable nursery and weaning techniques soon followed. The development of a high-quality, extruded diet opened the door to even greater production.

Cris has also strived to successfully develop his farm by capturing economies of scale and by increasing efficiency through mechanisation and the introduction of technology such as fish grading machines, larger production cages and pond aeration equipment. Of course, another essential ingredient, which is typical of many aquaculture farms, is the active participation of the family, and the development and support of key, multi-skilled staff.

There are still a few problems, however, such as predation by birds and water rats, the escape of fish from cages, fingerling losses due to disease, and relatively high maintenance costs, but these are the same sorts of factors encountered in many farming ventures.

Cris has been pro-active in industry-wide matters. He was the founding President of the Australian Barramundi Farmers Association, and serves on several State and regional advisory committees. While these activities are time consuming, he sees it as a personal contribution to the development of the aquaculture industry in Queensland.

Cris sees a bright future for barramundi farming, so long as existing domestic markets can be expanded with new products and new export markets can be developed. With good staff and good fortune, he may even get to go fishing again.

The product is generally transported by air to the large seafood markets in Sydney, Melbourne and other capital cities. Strict packaging regulations are imposed by the airlines. Road transport is used for local markets, and for transport of live fish.

Economics of production

The likely profitability of barramundi farming is calculated using a model farm which is based upon current industry practices in northern Queensland[1]. The model farm is 15 ha in area and produces an annual turnoff of 50,000 kg of whole, plate-size barramundi. To establish an early cash flow, it is assumed that 12—month-old fish are produced to provide returns in the first year. Production parameters and capital costs for the farm are given in Tables 1 and 2, respectively. The yearly income and operating costs are given in Table 3.

Table 1. Production parameters for model barramundi farm.

Ponds, 10 @ 0.5 ha	5
Saleable farm biomass/year (kg)	50,000
Age to turnoff (months)	12
Weight at turnoff (grams)	530
Feed conversion ratio	1.6:1
Death rate (%)	40
Fingerlings required/year	157,233

[1] A detailed report on the economics of barramundi aquaculture is available from the Queensland Department of Primary Industries.

Table 2. Capital cost of establishing the model barramundi farm.

Capital item	Cost of item ($)
Land	150,000
Pumps	35,000
Sheds and office	50,000
Aerator	24,700
Staff accommodation	20,000
Freshwater cages (frames and nets)	75,000
Coldroom	10,000
Walkways	15,000
Processing room	10,000
Feeding equipment	1,000
Nursery and tanks	40,000
Water monitoring equipment	4,000
Electricity connection (property and ponds)	55,000
Harvesting equipment	5,500
Utility	20,000
Processing equipment	4,000
Motorbike	7,000
Fish grading machine	9,500
Tractor (second-hand)	15,000
Ice machine	10,000
Slasher	4,000
Net and pond cleaning equipment	1,500
Boats	1,000
Workshop tools and equipment	5,000
Pond construction (including outlets/inlets, screens and pipes)	180,000
Miscellaneous items	5,000
Generator	30,000
Total	**$787,200**

Table 3. Yearly cash income and cash operating costs.

Cash income (50,000 kg @ $10.50/kg)	**525,000**
less cash operating	
Fingerlings	42,453
Feed (pellets)	80,800
Labour (owner/operator, permanent and casual)	125,000
Fuel, oil, repairs and maintenance	32,000
Electricity	25,000
Licences and permits	1,500
Marketing (freight, packaging and ice)	50,500
Administration	14,450
Farm cash income	**$153,297**

Discounted cash flow analysis is used as the economic evaluation method. This method evaluates a project over its estimated life, assumed to be 20 years, by discounting future cash flows to present values by the opportunity cost of funds employed (8% in this case). Three profitability criteria are shown here:

- Annualised profit—the net present value, the difference between the present value of cash inflows and the present value of cash outflows, expressed on an annual basis

Table 4. Summary of profitability criteria at different prices.

Average yearly price ($/kg)	Annualised profit ($)	IRR (%)	Payback period (years)
$8.50	-39,995	2	› 20
$9.50	10,045	9	20
$10.50	60,045	15	9
$11.50	110,045	23	6
$12.50	160,045	29	4

(note in this case the annualised profit is net after capital and labour);

- Internal rate of return—the rate of interest at which the net present value is zero. If funds can be borrowed at less than the IRR, the project will pay for itself;
- Payback period—the minimum number of years to recover project costs.

Prices for whole barramundi have fallen over the past few years. The analysis presented in Table 4 illustrates the impact of various price scenarios on profitability criteria. Payback period increases and annualised profit decreases as prices decline. Assuming production remains constant, the breakeven price, the price at which the annualised profit is zero, is $9.33/kg of whole barramundi.

The model barramundi farm analysed above is likely to be profitable, but there are other possible impacts to consider. Loss of production through disease, water quality problems, unforseen environmental conditions and lack of knowledge can severely affect the profitability of the enterprise. Another factor is the lack of markets, mentioned previously. Markets should be sought out and researched before venturing into barramundi production.

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Contact details can be obtained through the Freshwater Fisheries and Aquaculture Centre, Walkamin.

Key references

Barramundi Farming Information Package. Available through the Freshwater Fisheries and Aquaculture Centre, Walkamin. The package is regularly upgraded to include recent developments.

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Austasia Aquaculture is a bimonthly magazine which covers aquaculture in general, and often contains specific information on barramundi farming. A *Trade Directory* is also produced annually. Subscriptions can be made by contacting Austasia Aquaculture, PO Box 658, Rosny, Tasmania 7018 (phone: 03 - 6245 0064).

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Eels

Geoff J. Gooley

Introduction

There are four species of freshwater eels endemic to Australian coastal catchments, all belonging to the Anguillidae family. The two species with most potential for commercial farming are the shortfin eel, *Anguilla australis* Richardson and the longfin eel, *A. reinhardtii* Steindachner.

The shortfin eel is typically a temperate species but with a natural range which extends from south-east Queensland through to Victoria, Tasmania and the Murray River in South Australia. In contrast, the longfin eel is typically a more sub-tropical species but also has a broad natural distribution extending from northern Queensland through to eastern Victoria and north-eastern Tasmania.

Anguillid eels, including Australian shortfins and longfins, have a unique life-cycle in which the sexually mature adult eels migrate out to sea to spawn at depths of >300 m. The tiny larval eels, or 'leptocephali', are then thought to be carried in large numbers (hundreds of millions) by oceanic currents back to the continental shelf before they metamorphose into the next developmental stage known as 'glass' eels (up to 12–18 months of age). The glass eels are carried by tides into the estuaries of coastal rivers where they undergo further development to become 'elvers' (up to 1–3 years of age), which have adopted the adult form in all respects other than size. The elvers then undertake a more active secondary migration into the freshwater, upper reaches of the catchment where they grow and develop into sexually mature adults before returning to the sea to spawn (average 10–25 years of age, although this varies with species and location).

All Anguillid eels are thought to spawn only once. Australian shortfin and longfin eels are thought to spawn in the Coral sea, and the return trip from spawning grounds to fresh water and back can cover several thousands of kilometres. Because Anguillid eels cannot be successfully bred artificially, all aquaculture seedstock is obtained by harvesting natural stocks of glass eels and brown elvers annually during their respective migrations.

Markets and Marketing Issues

The world aquaculture production of freshwater Anguillid eels is currently estimated at more than 130,000 t/year, worth over US$1.3 billion. The bulk of this production occurs in Asia – with China producing approximately 50,000 t/year (mostly farmed), Japan 35,000 t/year and Taiwan 34,000 t/year – and to a lesser extent Europe (10,000 t/year). Approximately 70% of the Asian production is for the Kabayaki market. Kabayaki is a steamed, grilled, spiced eel product served on skewers with a specially prepared sauce. It is considered a delicacy by Japanese consumers and is in huge demand. Cultured Kabayaki eels are typically about 150–250 g in weight (average 200 g) and sold live, although frozen eels are also used.

Glass eels are the seedstock of choice for Asian and European commercial eel aquaculture which relies on the associated wild glass-eel fishery for *A. anguilla* in Europe (250–1000 t/year) and *A. japonica* in Asia (100–150 t/year). Glass eels range from approximately 5000–8000 individuals or 'heads/pieces' per kg at harvest. Market prices for these glass eels ranges from US$750–10,000/kg, with *A. japonicus* being the preferred and therefore higher-priced species in the Asian market.

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Australian longfin (top) and shortfin eels

In contrast to the increasing global demand for cultured eels, worldwide eel production is diminishing. The main reason is a decline in Asian and European glass eel stocks because of the combined effects of overfishing (for both glass eels and adult stocks) and environmental degradation.

Production of Australian shortfin and longfin eels is currently around 500–600 t/year worth approximately AUS$4–6 million. The vast majority of this production comes from 'stock enhanced' wild fisheries (also referred to in the industry as 'cultured' eels), in which wild elvers and sub-adult eels are taken from coastal rivers to lakes, swamps, wetlands etc., where they are left to grow to marketable size under natural conditions. Elvers are the preferred seedstock for such practices, and at present most such elvers come from Tasmania. When available, Tasmanian elver prices typically range from AUS$250 to 350/kg. Victoria has the largest annual production based on this practice, estimated to be approximately 250–400 t/year.

There is at present no commercial supply of Australian glass eels, nor are eels produced in commercial quantities in Australia by intensive aquaculture. An assessment of Australian glass-eel stocks and the development of intensive-culture technology is being undertaken for shortfin and longfin eels as part of a collaborative R&D project between Queensland, NSW, Victoria and Tasmanian state fisheries with additional funding from the Fisheries Research and Development Corporation. Pilot-scale commercial production is also under way in some states, with state agencies in Victoria, Queensland and NSW providing access to limited quantities of glass eels (from 50 to 200 kg/State) and intensively cultured elvers (Victoria only) on a trial basis.

The sustainable yield of Australian glass eels for aquaculture seedstock is not known. There appears to be little commercial potential for exporting Australian glass eels or elvers as a commercially valuable and relatively limited natural resource,

Internationally, market prices for cultured eels and eel products vary with species, country and product type and quality. Most Australian production is exported to European (Germany, The Netherlands) and Asian markets (Hong Kong, Taiwan and Japan) as adult size (> 1 kg), fresh, chilled or frozen whole fish. Larger longfins are sometimes exported live into selected Asian markets (Taiwan and Hong Kong), and some value-added smoked products are also supplied to the local market. The range of existing and potential 'cultured' and wild eel products from Australia, together with nominal/estimated wholesale unit prices (delivered) are given in the table above.

Product (export, unless otherwise stated)	Wholesale Price (FOB) AUS$/kg
Large longfin (>2–15 kg), live (to Asia)	7–17
Large shortfin (>1 kg), live (to Asia)	12.5
Large shortfin (>1 kg), whole, chilled/frozen	8–12
Large shortfin (>1 kg), gutted, skin on, frozen	12–15
Kabayaki (150–200 g; whole, live/frozen)	estimates 10–18; 25–30[a]
Processed Kabayaki	estimate >50[a]
Processed/smoked whole/gutted large eels—export	estimate >50[a]
Processed/smoked whole/gutted large eels—local	12
Restock (5–10 g eels for stock enhancement)—local	estimate $350–750[a]

[a] Estimates based on industry advice

Because there is no Australian intensive eel industry, the marketability and benchmark prices of cultured shortfin and longfin eels are unknown. The greatest potential appears to be in the production of smaller eels for the Japanese Kabayaki market. Value-adding through local processing is another means by which profitability and marketability can be enhanced. At present few eels are processed in Australia, although the appropriate infrastructure and expertise exist for other seafood products. Also, 5–10 g elvers from glass eel seedstock could be intensively produced for commercial stock enhancement purposes in existing wild fisheries such as in Victoria.

Grading intensively-farmed shortfin eels

Production requirements

In the face of unsatisfied market demand and declining world production, increased attention is being paid to the development of intensive culture technology and the use of glass-eel seedstock.

Paste feeding of tank-reared shortfin elvers

Australian eel production is only likely to exceed current levels substantially if intensive aquaculture practices are adopted based on the sustainable use of wild glass-eel seedstock. Ultimately, the limited availability of such seedstock will probably also constrain any further development of the Australian industry.

Eel farming around the world employs a variety of reliable, well established systems and technologies for intensive production, ranging from relatively low-density (< 5–10 kg/m^3), flow through pond culture under ambient conditions, to semi-intensive (10–100 kg/m^3) pond and tank culture under semi-controlled conditions, and super high-density (>100 kg/m^3) in closed loop (recirculation), tank culture in a completely controlled environment.

Culture tanks and ponds vary in size from small nursery tanks (e.g. 1–10 m^3 capacity) to large grow-out ponds (e.g. 0.05–0.2 ha surface area). Water supplies for culture systems also vary from fresh to brackish, and from surface waters at ambient temperatures, to heated industrial effluent and geothermal artesian aquifers. The use of greenhouses is common in Japan, primarily as a cost-effective means of increasing water temperature and therefore growth rates.

Preliminary trials with shortfin eels suggest that water temperatures for optimal growth and survival range between 23 and 28°C (average 25°C), with feeding becoming irregular at temperatures below 15 to 20°C. In Australia, suitable production temperatures can be found under ambient conditions in eastern Australia at more northerly latitudes (e.g. northern NSW and Queensland). At more southerly latitudes, ambient temperatures would permit only seasonal production unless the water is heated in some way. Options for cost-effective heating in these areas include the use of controlled environment, closed-loop systems, polythene greenhouses and ground water.

Key messages

- Export demand
- Cultured Australian eel market untested
- Two potential local species
- Glass eel supply is major constraint
- Trend towards intensification of production
- Overseas production technology available

Closed-loop, or recirculation systems, are becoming increasingly popular as a means of providing controlled environment conditions for year-round production, for reducing demand for fresh water and discharge of nutrient-rich effluent, and for securing the system to ensure the minimal escape of exotic stocks and disease pathogens to natural waterways. The major components of such systems include mechanical filtration (e.g. sand filters, drum/micro-screen filters, hydrocyclone filters, plated settlement tanks etc.) to remove suspended solids, biofilters (e.g. rotating drum/disc filters, trickling filters, upwelling filters, fluidised bed filters etc.)

to remove dissolved metabolites, mechanical aeration or oxygenation to increase dissolved oxygen levels, sterilisation units (e.g. UV filters, ozone generators etc.) to destroy pathogens, and miscellaneous pumps, pipes and valves to reticulate the water through the system. The need for increasing levels of filtration, including solids removal and biofiltration, and supplementary aeration/oxygenation increases with the increasing percentage of recirculation, stocking density, feed rates and water temperature. The degree of effluent treatment and re-use, and options for nutrient-rich effluent disposal vary with the environmental licensing conditions, the quality and quantity of effluent, the system's location and the efficiency of design.

Government licensing requirements and associated costs vary from state to state, but in most cases include some form of culture permit to enable commercial production and sale of aquaculture produce, local government planning and health regulatory permits, and water pumping and/or discharge permits.

Varieties/breeds

The Anguillidae form a relatively cosmopolitan family of predominantly freshwater eels, which contains the one genus with 16 species distributed throughout the world. Of these, *A. japonica* and *A. anguilla* are the two most commonly cultured species. In addition to shortfin and longfin eels in Australia, commercial aquaculture of *A. rostrata*, endemic to the coastal waters of North America, is also under development.

Longfin eels are sometimes mistakenly referred to as 'conger' eels. True conger eels are in fact mostly marine and belong to a different family, the Congridae. Other Australian Anguillid species which have not been evaluated for their aquaculture potential are the northern eel, *A. bicolour*, and the South Pacific eel, *A. obscura*, both of which have a fully tropical range in northern Australia.

Tank-reared shortfin glass eels

Husbandry

Almost all forms of intensive eel farming around the world rely on artificial foods: mostly high-energy, protein-rich, compound diets in the form of a moist paste for glass eels, and steam-pressed or extruded pellets of varying sizes for later developmental stages. Natural feeds such as aquatic worms (e.g. *Tubifex* spp.), brine shrimp and minced fish have been used successfully to wean Australian glass eels onto artificial foods. Artificial pastes and pelleted diets imported from Taiwan have also proved suitable and these products are now being formulated and manufactured in Australia for shortfin eels.

Food conversion ratios (FCRs) for Asian and European intensive-culture systems vary between 0.9:1and 1.9:1 (kg food per kg fish weight). Industry standard FCRs have yet to be determined for Australian eel culture systems, but likewise will vary with species, size, system design, food type, water temperature and quality. Growth rates of Anguillid eels, including the Australian species, are inherently variable and frequent mechanical grading throughout the production cycle is necessary (usually every 4–8 weeks). Eels are also naturally aggressive, highly carnivorous, top-order predators with a relatively large mouth. In high density aquaculture, such grading will minimise the risk of cannibalism and encourage efficient feeding behaviour and food conversion within the system.

The maintenance of optimal water quality conditions is critical to ensure adequate growth and survival under intensive aquaculture. Enhanced production through increased stocking densities and growth require increased feed rates, leading to a further increased, organic, loading on the systems. Water quality is managed through appropriate water exchange and/or water filtration, together with the application of appropriate husbandry (use of high quality feeds, optimal feeding regimes, routine maintenance and cleaning of the culture system etc.). Key water quality variables such as temperature, dissolved oxygen, pH and total ammonia should be monitored regularly.

Pest and disease control

Glass eels collected in salt water are routinely acclimatised to fresh water for intensive grow-out almost immediately, thereby eliminating the resident, natural, marine, parasitic fauna of the eels. In Australian systems, subsequent outbreaks of mostly common bacterial, fungal, protozoan and larger ectoparasitic disease pathogens within freshwater culture systems are routinely treated with short to long term salt baths at concentrations of 5–10 g salt/L of water.

Harvest and postharvest handling requirements

Cultured Australian eels need to be handled and processed in much the same way as for the commercial fishery. This includes freshwater purging of the fish in tanks or cages, followed by cleaning (evisceration) for some products, packaging and chilling (ice slurry), smoking or snap freezing before delivery to markets. All the commercial fish-processing facilities and procedures designed for human consumption must meet local and state government health standards. Processing facilities approved by the Australian Quarantine Inspection Service (AQIS) are required for the export of Australian seafoods, including eels. Cultured Kabayaki-size eels exported live to Asian markets would need to be purged in cold fresh water, chilled (to 4–5°C) and packaged in oxygen-filled polyethylene bags transported inside insulated polystyrene containers.

In general, cultured eels intended for export markets should be purged to remove any foreign residues or off-flavour, should be of uniform size, quality (particularly fat content and skin texture) and appearance (not damaged), and should be appropriately packaged (depending on whether live, chilled or frozen) to prescribed quality standards.

Economics of production

With intensive aquaculture, Australian shortfin and longfin eels could be produced from glass- eel seedstock to a marketable Kabayaki-size product in approximately 18–24 months. Refinement of this technology through R&D and identification of more optimal production parameters may lead to production of such a product in 12–18 months in the short to medium term.

Asian industry standards for *A. japonica* stipulate 600–900 kg of marketable eel biomass (Kabayaki product; based on up to 90–95% survival) per kg of glass eels within 9–12 months from the glass eel stage. By contrast, total survival for *A. anguilla* is reported to be as low as 10–45% for the same period, with conversion rates as low as 110–130 kg of marketable eels for every kg of glass eels. Generally, larger glass eels collected earlier in the season tend to exhibit higher survival and growth throughout the production cycle, in comparison with smaller glass eels collected later in the season. Conversion rates for intensively cultured Australian eels will ultimately depend on the development of customised and efficient, intensive, culture technology and the inherent suitability of the Australian species to adapt to such high-density systems.

Key statistics

- Japan is the main consumer of Kabayaki eels; value of imports estimated at >$1 billion annually
- World-wide glass eel harvests range from 350–1150 t/year; prices range from US$750–10,000/kg
- Australian eel production from 'wild' fishery approximately 500–600 t/year, worth about $AUS4–6 million; insignificant aquaculture production.

The capital costs of eel-production systems vary directly with capacity and the degree of intensification and technical sophistication: i.e. the bigger, more intensive the system, the more complex the design and higher the purchase cost. Operating costs depend primarily on the efficiency (kg fish/m^3 of water) and capacity of the system design. Major recurrent production costs include depreciation on capital infrastructure, interest on borrowed funds, seedstock (glass eels, elvers), water, labour, feed, energy (for recirculated, heated systems), system maintenance, processing, packaging and freight.

As for Asian and European intensive eel farms, economies of scale will apply in establishing overall profitability for Australian eel farms – costs per unit of production will decrease with increasing system size and capacity. As a starting point, Australian producers should expect production costs to be about AUS$10–15/kg during the initial research and developmental phase of the industry. Longer-term production costs and profitability ratios are unknown at this stage. However it is likely that with adequate glass-eel supplies, more efficient culture systems and feeding regimes, and improved value-adding and marketing strategies, intensive freshwater eel farming in Australia could well prove to be an economically viable industry.

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Inland production of marine fish

Stewart Fielder
Geoff L. Allan

Introduction

Inland saline water is already successfully used to grow barramundi (*Lates calcarifer*) in NSW in an indoor, intensive recirculating system. Similarly, it has been used to farm a range of algae, crustaceans, and finfish such as tilapia, red drum, sea bream, eels and channel catfish in North America and the Middle East.

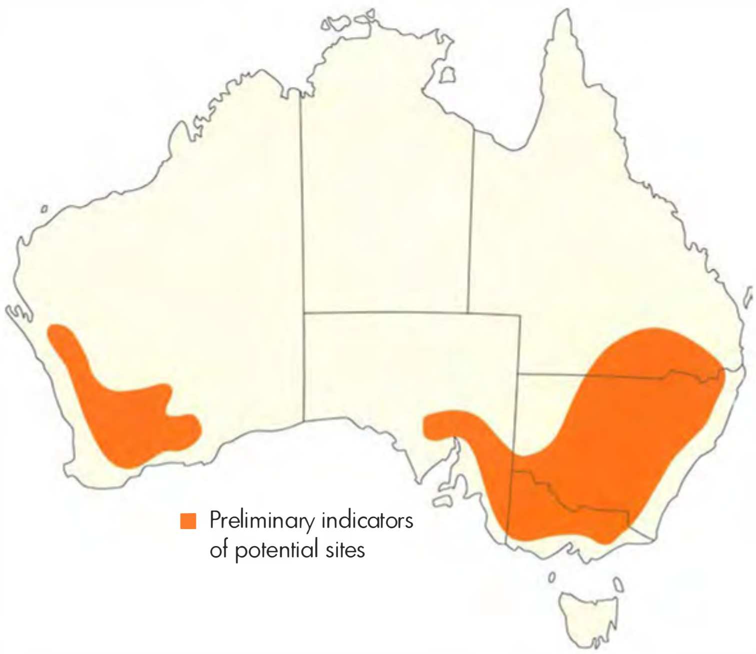
In Australia, investigations are under way to determine if snapper (*Pagrus auratus*), mulloway (*Argyrosomus japonicus*), black bream (*Acanthopagrus butcheri*), Atlantic salmon (*Salmo salar*) and the freshwater silver perch (*Bidyanus bidyanus*) can be farmed in inland saline water. Australia has a great deal of inland, saline ground water and excellent potential exists to use this for the farming of temperate marine finfish.

Rising saline ground water tables and increasing river salinity are major problems in the semi-arid agricultural regions of Australia. In order to retain arable land, a method of pumping saline ground water into purpose-built, on-farm evaporation ponds or sacrificial basins, is being used in Western Australia, South Australia, New South Wales and Victoria. These evaporation ponds may be suitable for growing marine fish if the water chemistry is suitable for their survival and growth.

Although a number of species could be grown in inland saline ponds, this article focuses on snapper and mulloway, temperate species being investigated in NSW. General fish husbandry for barramundi and silver perch is covered elsewhere in this book.

Snapper is seen as an excellent candidate for farming in temperate Australia. It is the same species as the Japanese red sea bream, which has been cultured for more than 20 years in Japan using intensive larval rearing followed by grow-out in sea cages. In 1987, aquaculture production in Japan totalled 38,000 t. Snapper is a popular commercial species and commands a high market price.

Mulloway is also an excellent candidate for inland farming because it is very similar to the American red drum. Technology for red drum production is well developed and the species has been successfully grown in inland saline ponds in the USA. Mulloway are a popular commercial and recreational species in Australia and the wild fishery is declining. Mulloway also command a high market price.



The technology for snapper and mulloway production is developing and a commercial industry for coastal farming of snapper is beginning in Australia. However, a major constraint to industry development is the limited number of suitable sites for sea-cage farming. To date, production of market-size snapper and mulloway in Australia has been confined to a pilot commercial scale research project conducted by NSW Fisheries using sea cages in Botany Bay. However, a commercial sea-cage farm in SA should harvest snapper soon.

If research demonstrates that marine fish can be farmed in inland saline water, a new industry will be developed for inland farmers. Given a sound understanding of primary production and the associated pitfalls, these farmers will need to develop fish husbandry and marketing skills.

Marketing issues

Not enough wild-caught snapper are at present reaching markets in Australia. Catches in New South Wales declined from 1000 t in 1980 to 513 t in 1994–95, and the deficit is currently made up with imports from New Zealand. There is clearly a market for farmed snapper, at least to replace imports.

Because the snapper farming industry is developing, only small quantities of snapper were sold in 1995 as fresh, whole or live product (400 g and up). These fish were sold on the Sydney auction floor and the price ranged from $5.50 to $10.00/kg. Live fish sold in Sydney returned $17.00/kg.

The dark skin colour of farmed snapper resulted in lower prices than wild-caught snapper of the same size. Once a technique was developed to lighten the skin colour of farmed snapper, higher prices were received.

To date, only small numbers of mulloway have been farmed by NSW Fisheries, so only limited marketing has been possible. Some buyers believe that small mulloway (< about 3 kg), referred to as 'soapies', are not very palatable. However, live mulloway of 1–1.5 kg sold to the Asian restaurant trade in Sydney were highly regarded. The preferred market size for farmed mulloway appears to be 500–700 g.

Other farmed fish, such as barramundi, are sold direct to wholesalers on consignment.

A substantial export market for snapper exists in Asia, particularly for live fish.

Production requirements

Marine fish could be farmed in inland Australia by using a range of techniques. The first would involve grow-out of fish directly in the evaporation basins. Alternatively, fish could be grown in floating cages situated in the evaporation basins. This is the most common technique used to farm barramundi in freshwater ponds in north Queensland. Another technique, which requires greater infrastructure and capital inputs but provides more control over the farming environment, involves grow-out of fish in

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intensive, indoor recirculation systems. Barramundi are already farmed in this manner in inland NSW using saline ground water.

Snapper and mulloway are temperate marine species and have been cultured in coastal NSW in temperatures ranging from 13° to 25°C and salinity's of 30–35 ppt. Growth of both species is affected by water temperature. However, low temperatures of 15 to18°C cause a greater reduction in growth of snapper than mulloway. Mulloway also grow almost twice as quickly as snapper. The upper and lower temperature and salinity tolerances for Australian snapper are not yet known, but Japanese red sea bream can survive temperatures in the range of 5.5° to 30°C and salinity as low as 16 ppt. Mulloway can tolerate a wide range of salinity from 5–35 ppt.

Inland areas where snapper and mulloway could potentially be farmed will depend on factors such as the type of production system used, the chemistry and temperature of the pumped ground water, and the volume of daily exchange water. Open-pond production will most likely be restricted to the southern inland areas of Australia because of the extremes in ambient air temperature. Pond construction will require either impermeable soils or plastic liners. Intensive indoor systems could be operated anywhere in Australia provided that the saline ground water chemistry is suitable. The cost of production of all farming systems will be influenced by the proximity to infrastructure and markets.

The main environmental feature of using inland saline water for fish culture is that it makes it possible to use ground water and land degraded by salt intrusion. Pond-based fish-farming would involve no release of effluent water into natural waterways, so the environmental impact of farming activities would be limited.

Key statistics

Statistics for farmed snapper and mulloway are not available. Statistics for the 1994–95 Australian wild catch fishery for snapper are:

State	Catch (t)
NSW	513
Vic	58
Qld	68
WA	2540
SA	318
Export	Not Available
Import (New Zealand)	684

Varieties

Apart from Atlantic salmon, there has been no selective breeding of marine fish species farmed in Australia. First and second generation hatchery-reared broodstock are available for some species such as snapper, mulloway and barramundi but broodstock selection has not yet become a component of formal breeding programs.

Fish husbandry

A reliable supply of cheap, healthy fingerlings is essential for snapper farming. To date, only relatively small numbers (tens of thousands) of fingerlings have been produced by research organisations in Australia for grow-out in pilot-scale projects. Several commercial hatcheries are now poised to produce snapper fingerlings and research is going on to improve existing and develop new techniques for low-cost fingerling production.

The Australian snapper is an excellent candidate for farming in saline groundwater in temperate areas of inland Australia.

Mulloway can grow in water with salinities ranging from almost fresh to full strength seawater and have excellent potential for farming in inland saline groundwater.

Methods for spawning wild and captive broodstock are fairly well developed. Induced spawning occurs after the injection of reproductive hormones or natural spawning can occur after the manipulation of temperature and photoperiod. Several research facilities have been able to induce out-of-season spawning by controlling the temperature and photoperiod, thus potentially allowing year-round spawning.

The main method of snapper fingerling production in Australia has used intensive, clear-water methods. Intensive hatcheries need high-technology, dedicated facilities, excellent saltwater quality and well-trained staff and consequently are expensive to operate. Some early success has been achieved with the use of extensive, fertilised, brackish-water ponds for snapper fingerling production and large numbers of mulloway have already been produced using this method. This technique is used to rear a wide range of marine and freshwater fish species; it requires less sophisticated facilities and is easier to manage than intensive hatcheries. The cost of fingerling production is also lower when using extensive rather than intensive rearing techniques. Research is continuing to develop extensive techniques for snapper.

In an intensive hatchery, the larvae must then be fed plankton, which is specially grown. In extensive systems, natural plankton is encouraged to grow in ponds by the addition of fertilisers. Once the larvae have metamorphosed into true fish (34–39 days old and 10–12 mm), they are generally transferred from the hatchery to a nursery, where they are weaned off live food onto a formulated pellet diet. The fingerlings will remain in the nursery until transfer to the grow-out site which usually occurs when fish are 40 mm long.

The fingerlings are then released directly either into earthen ponds or floating cages for grow-out. To date, snapper and mulloway have not been farmed to market-size in ponds in Australia, but there are no obvious reasons why this will not be possible. Ponds used to grow freshwater fish are usually 0.1–1 ha in area and 1–1.5 m deep. Fingerlings are generally stocked into aerated ponds at 5,000–20,000/ha and harvested at 400–500 g. Snapper and mulloway are fed a formulated pellet diet which is readily available from several feed producers. Smaller fish need frequent feeding, up to six times a day, but as fish become larger feeding can be reduced to once or twice a day.

Good water quality is essential for the good growth and survival of any farmed fish. Dissolved oxygen, temperature, pH and water clarity must be monitored regularly. Depending on stocking density and the quantity of food required, water exchange may be necessary to optimise the ponds' water quality.

Key messages

- Excellent potential for new industry
- Potential for limited environmental impact
- Water resource currently not used
- Techniques need developing

Snapper farmed in sea-cages in Australia reached market size (400 g) in 20–24 months. Mulloway grew faster than snapper and reached 1100 g in 26 months. Fingerlings were stocked in late summer and consequently were grown through two winters. However, if fingerlings were available for stocking into ponds in early spring, the time to market could be reduced to 12–18 months.

Pest and disease control

Farmed marine fish are susceptible to a range of pests and diseases. Disease outbreaks often occur after the fish are stressed as a result of suboptimal environmental conditions or husbandry practices. Low water temperature, dissolved oxygen, and pH outside of the 6–9 range can cause stress which can result in disease. Rough handling of fish during transport to the farm or sorting for market, and overcrowding, can remove skin and scales from the fish which then become more susceptible to infection.

Vibriosis is a bacterial infection which has caused the death of snapper farmed in sea-cages. The dominant bacterium, *Vibrio splendidus*, was isolated from dying snapper when water temperatures declined from 20° to 15°C. Vibriosis typically appears as white, circular lesions on the sides of fish. Infected fish are dark in colour, sluggish, do not feed well and can die in large numbers. Fingerlings are usually more susceptible to vibriosis than advanced fish. Outbreaks of vibriosis can be controlled by antibiotics, such as oxytetracycline, added to the pellet diet. Other options for prevention may include stocking fingerlings well before the onset of winter and avoiding handling the fish during winter.

The gill fluke parasite, *Bivagina pagrosomi*, has also caused disease in farmed snapper. The adult flukes attach to the gills and skin and when present in large numbers can cause severe blood loss. Infected fish are dark and sluggish and do not feed well. Gill flukes can be treated by subjecting fish to a formalin bath. Fish infected with gill flukes may also be more susceptible to secondary bacterial infections.

One viral disease, lymphocystis, has been found in snapper. It generally does not kill but disfigures the external appearance of the fish by forming wart-like lesions. There is no known treatment and fish generally overcome the infection in time.

Mulloway farmed in sea-cages did not suffer much disease but cannibalism and cormorants caused some deaths. Cannibalism can be reduced by the regular size-grading of fish. Cormorants are fish-eating birds and are a problem for farming fish in ponds and sea-cages. The ponds must be covered with bird-proof netting to keep the birds out.

Harvesting, processing and packaging

The harvesting of fish from ponds initially requires the concentration of the stock into an accessible area. This can be achieved either by draining water from the pond or running a seine net through it. The fish are then lifted out in hand nets or by mechanical devices such as fish pumps. Fish are usually euthanased by placing them directly into an ice/brine slurry. Freshwater fish can be affected by 'off'-flavours and require 'purging'. Purging involves holding the fish in tanks supplied with clean water, usually for one to three weeks before market. It is unlikely that 'off'-flavours will be a problem in inland saline water, but if they are, then purging will be necessary.

Inland saline groundwater has potential for use in ponds or intensive systems to farm marine fish. Similar facilities to these freshwater ponds, used for barramundi, are currently being evaluated.

Most farmed fish are sold with the head on and gut in, so processing is minimal. The fish are transported to a licensed packing shed, removed from the slurry and packed into lined, Styrofoam boxes. At least one layer of crushed ice is placed on the fish before the box is sealed. The chilled product is then transported to market by road or air.

Fish must be handled as little as possible to reduce external damage and keep them looking their best. Specialist transporting facilities such as tanks with more than 2000 L capacity and filtration and oxygenation are needed to carry high densities of fish.

Economics of production

Insufficient data on the farming of fish in inland saline water are available to estimate the economics of production. However, an economic analysis of the sea-cage farming of snapper and mulloway is made in *Proceedings of a Marine Finfish Farming Workshop*.

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Marron

Craig Lawrence

Introduction

Marron (*Cherax tenuimanus*) is a large freshwater crayfish native to the main permanent rivers in the forested, high-rainfall areas in the south-west of Western Australia.

Marron is one of the largest freshwater crayfish in the world and, consequently, has been the subject of continued interest for aquaculture.

Marron farming was pioneered by Dr Noel Morrissy in the mid 1970s. His initial research achievements included elucidation of the life cycle of marron. Over the ensuing 25 years he developed a system for the semi-intensive farming of the species. Much of this information is published and is available to prospective farmers. Consequently, there is now a good understanding of the basic biology and aquaculture requirements of the species, as opposed to early attempts at farming in the 1970s, when very little was known about marron.

Marron, like other Australian freshwater crayfish, are much in demand in international markets because of their large size, high quality, acceptance by European markets as a replacement for diminishing stocks of their own native crayfish, freedom from major diseases and ability to be landed alive in the major international markets.

Markets and marketing issues

The principal export markets for marron, as a live product, are in Asia and Europe. Marron farmers currently sell both small juveniles for stocking ponds and larger marron for local and export sales.

One of the key strengths of marron is that they can be exported alive, out of water and arrive in prime condition not only in capital cities in Australia, but also on high value markets in Europe and Asia. International demand for freshwater crayfish is expected to continue to increase. This is the result of a number of factors, but particularly continuing demand from traditional European consumers of freshwater crayfish combined with decreased domestic supplies there because of crayfish plague, a disease which has swept through Europe killing many of their native populations of freshwater crayfish. Australia is the only continent with freshwater crayfish that have not been infected by the disease, and our strict quarantine regulations should ensure that this valued status is maintained.

Marron are marketed either by individual farmers or by co-operatives which combine the produce from a number of small farms in order to fulfil larger orders. The latter is a recent development. Grades and the prices that farmers receive for their marron vary throughout Australia. Average grades and farm-gate values are presented in Table 1. Higher prices are paid for marron which are purged, graded and/or packed by the farmer. Markets generally pay higher prices for larger marron, which reflects the demand for larger crayfish and the increased time required to grow larger animals.

Table 1. Average farm-gate prices received for various size grades of marron.

Size grade	Farm-gate price ($/kg)
71–100 g	16.00
101–130 g	18.00
131–160 g	20.00
161–190 g	22.00
191–220 g	24.00
220 g+	26.00

The annual production of marron has increased steadily since 1979, aside from a decrease in the late 1980s, when the main focus of farmers shifted from production of marron ready for market to supplying juveniles to stock new and expanding farms (Fig. 1).

Recently there has been a resurgence of interest in marron farming, in part because they are the highest valued freshwater crayfish farmed in Australia. This has resulted in significant investment in well designed and constructed purpose-built farms, and increased production from farms in Western Australia and South Australia.

Production requirements

Marron are currently farmed in Western Australia, South Australia and NSW . They are not permitted in Victoria. The area of Australia potentially suitable for marron farming, shown on the accompanying map, is determined by temperature, water supply and the occurrence of clay soils suitable for ponds.

Marron do not grow at temperatures below 12.5°C. The temperature for maximum growth is 24° C. Above this temperature, marron growth declines rapidly, and the animals cannot survive temperatures of 30°C for long periods. mortalities occur at 30°C and above, depending on exposure time.

Marron occur in waters which generally have pH levels ranging between 7.0 and 8.5.

Dissolved oxygen levels should be maintained at or above 6 parts per million (ppm) and marron become stressed when levels drop below 3 ppm. As marron are susceptible to low levels of dissolved oxygen, the use of aeration is recommended in ponds to maintain dissolved oxygen at adequate levels and to avoid stratification, stagnant bottom water and anoxic sediments.

Although marron can tolerate salinities ranging from freshwater to 15 parts per thousand (ppt), low salinities are most suitable for farming, as growth decreases when salinity is above 6–8 ppt.

Varieties

Marron are native to the south-west corner of Western Australia, and a number of licensed hatcheries operate in that State. These sell juvenile crayfish under 1 year old (0+) for stocking farms in Western Australia and elsewhere.

Most established farmers produce their own juveniles for stocking their ponds. Marron mate in early spring and, depending on the size the females, incubate 450–900 eggs, until releasing juveniles in early summer. Hatchery performance is measured as the

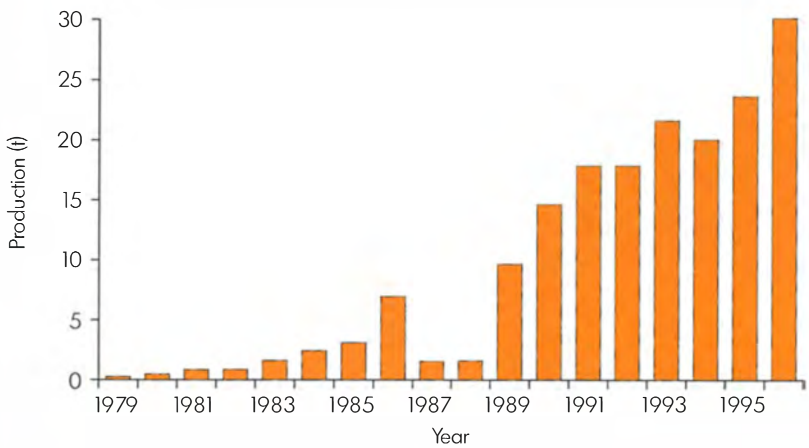

Figure 1. Annual production (t) of marron in Australia, 1979–96.

number of surviving 0+ juveniles reared per female—200 is considered excellent.

About the author

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Broodstock marron are at least 2, and usually 3 years old. During the non-breeding season, they should be held in small earthen broodstock ponds at a density of four individuals per m^2, a ratio of one male to every three females and be well fed.

As the breeding season approaches, broodstock should be transferred into 100–150 m^2 spawning–nursery ponds for mating. Approximately 75% of $2+^+$-year-old females become berried, after which the males and non-berried females should be separated from the berried females. A supply of artificial weed, which can be examined periodically, makes it easier to monitor released juveniles, and provides shelter for them. To prevent cannibalism, the adult females should be removed immediately after the juveniles (0+-year-olds) are released.

At least three varieties of marron exist within the range of this freshwater crayfish. The potential of these varieties, and of others that may also be present, has not yet been scientifically evaluated.

The marron (*Cherax tenuimanus*) is native to streams in south-west Western Australia.

Fish husbandry

In Western Australia, attempts have been made to culture marron in farm dams, ponds, tanks and battery cultures. The success of battery and tank cultures has been limited by the unavailability of a suitable diet and poor growth at high density.

Although both farm dam and pond cultures have been exploited in Western Australia, the efficiency of these two methods varies considerably. Unfed farm dams usually produce only 100–300 kg/ha/year, while purpose-built semi-intensive ponds, incorporating a daily feeding regime, have been producing 1000–4000 kg/ha/year, depending on stocking rate. In addition, semi-intensive pond production permits draining and grading of stock. This enables the management of a marron crop to maximise both biological and economic productivity.

The relative merits of semi-intensive pond culture and farm dam culture of marron are described by Morrissy (1992).

Semi-intensive grow-out ponds are usually rectangular and 1000 m^2 in surface area. Although larger ponds may be built, they are more difficult to manage. Ponds should have a maximum width of 20–25 m and be situated with their long axis parallel to the prevailing wind direction to increase aeration.

Marron ponds should be located side-by-side with an access road between each pond. Ponds should have paddlewheel aerators and be constantly topped up to replace water lost through evaporation and seepage.

Key statistics

Most marron production comes from semi-intensive farms in Western Australia. This industry has demonstrated steady growth over the past 10 years. More recently, marron have been introduced into Kangaroo Island in South Australia, where a number of farms are now in production.

Table 2. Australian marron production (t)a.

Year	SA (t)	WA (t)	Total (t)
1987	0	1.8	1.8
1988	0	1.9	1.9
1989	0	9.4	9.4
1990	2.1	12.1	14.2
1991	2.5	15.1	17.6
1992	1.1	16.4	17.5
1993	1.8	19.5	21.3
1994	3	16.7	19.7
1995	5	18.1	23.1
1996	6	23.5	29.5

Key messages

- Marron is one of the largest freshwater crayfish in the world
- Marron can be live-exported to international markets
- There are large international markets for our live, disease-free marron

The pond floor should slope from a minimum depth of 1.0 m to a maximum of 2.0 m, with a gravity-feed drain pipe in the deep end. The pond floor should be well compacted and consolidated with road limestone or gravel, upon which should be placed between 100 and 200 artificial weed bunches per 1000 m^2 to provide shelter. The bottom gravity-feed drain should have a 3 m^2 concrete collection basin around the base to facilitate harvesting.

Semi-intensive grow-out ponds require overhead bird mesh and artificial shelters to prevent predation. Ponds also require perimeter fencing to prevent marron from crawling out and water rats or other predators from entering.

The 0+ juvenile marron should be held in smaller spawning–nursery ponds (see above) for around 6 months. The grow-out ponds should be stocked with 0+-year-old juvenile marron in mid winter at a density of 3–5 per m^2.

Marron are omnivorous, feeding on detrital material such as rotting organic matter at the bottoms of rivers or ponds.

Commercial operators use a combination of a pelleted marron diet and natural foods in outdoor earth ponds. Pelleted diets added to marron ponds feed the marron directly, but also contribute to establishing a natural food chain in the pond. Although marron have been reported to grow to 2 kg, it is more economic to harvest farmed marron at much smaller sizes.

Depending upon culture conditions such as water temperature, nutrition and stocking density, marron can grow to 60–100 g within 12 months and to 100–300 g within 24 months.

Marron have a commercial 'tail with shell' recovery rate of 43%. This is higher than the commercial tail recovery rate for other cultured freshwater crayfish and compares favourably with the 40% obtained from marine rock lobsters.

For further information on culturing marron, the reader should consult 'An introduction

A typical marron farm showing breeding and grow-out ponds.

to marron and other freshwater crayfish farming' by Dr Noel Morrissy (1992), published by the Fisheries Department of Western Australia.

Pest and disease control

The shells and gills of marron, in common with those of all freshwater crayfish, may be home to a number of very small, attached animals called epibionts. They include the stalked, ciliate protozoan *Epistylis* and a small flatworm *Temnocephala*, and they cause problems only if they occur in large numbers and affect the marketing appearance of the marron. Although epibionts do not directly harm the crayfish, their occurrence is symptomatic of poor water quality and slow growth.

Only two diseases have been reported in marron: microsporidiosis caused by a pleistophorid; and *Thelohania*.

Thelohania is a protozoan which causes 'Cotton tail' or 'porcelain disease'. It has been reported in crayfish in the eastern States and in gilgies in Western Australia, but has not been found in marron in WA. Consequently, the translocation of crayfish should be strictly controlled to ensure that *Thelohania* is not introduced into disease-free stocks from Western Australia.

The importation of all overseas crayfish species into Western Australia is prohibited, since they carry the crayfish plague fungus *Aphanomyces astaci*, to which all Australian crayfish are very susceptible.

After draining the pond, marron can easily be collected from the pond floor.

Harvesting and postharvest handling

Unlike some other freshwater crustaceans, marron do not burrow to escape drought. This facilitates harvesting and ensures that the integrity of pond walls is not compromised.

Marron are usually harvested by draining ponds and collecting animals by hand. It is preferable to harvest during the coolest part of the day. After harvest marron need to be gill washed immediately, then held in a cool, moist atmosphere. This prevents mortalities from infections by bacteria in bottom sediments trapped in the gill chamber.

As marron are exported alive, very little processing is required. Before packing for export the processor places freshly harvested marron into purging tanks. The marron remain in these tanks, where they are not fed, for a minimum of 48 hours to purge their hind guts and improve the flavour.

The marron are graded according to condition and the weight grades presented previously (Table 1).

Marron can live for many days out of water, and can be shipped alive if held in cool, moist air. If immersed in water without aeration they will drown. To ensure that the marron arrive at their destination in top condition, before export they are cooled, then packed between layers of foam in polystyrene boxes with ice bottles.

Economics of production and processing

In general the establishment costs for a semi-intensive marron farm average \$50–\$60,000 per hectare of water area of ponds constructed. This includes the cost of pond construction, consolidation, bird netting, electricity, aeration and drains. When managed correctly these semi-intensive ponds will optimally yield 2500 kg of larger marron per hectare of water area per year, but up to 4000 kg of smaller marron can be produced per hectare.

Because of the commercial confidences of existing marron farms, accurate information on income and operating costs is hard to obtain. Recent economic evaluations have shown that a properly constructed and managed, marron farm will return a gross income of $40,000 per hectare of ponds per year, with operating costs around $15,000 per hectare per year. This provides the farmer with a net income of around $25,000 per hectare of ponds per year.

Consequently a marron farmer can expect to receive a return on investment of around 30%, which compares favourably with other forms of primary production. Like all forms of farming returns may vary with farming methods and site characteristics.

A job well done. Harvested marron about to go to market.

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Prawns

Peter C. Rothlisberg

Introduction

Australian prawn (= shrimp) production has been established over the past ten years along 2000 km of the eastern coastline (from the Clarence River, NSW to Mossman, North Queensland) and in the Northern Territory. Australia has a number of species to choose from, relatively unpolluted coastal waters, a low incidence of disease, and tight environmental regulations—all of which point to the potential for a sustainable industry.

The growth of the industry has been steady in spite of some early cases of poor site and species selection and some recent setbacks with disease and postlarval supply for one species (the black tiger prawn, *Penaeus monodon*). These setbacks have been offset by the rapid growth of the kuruma prawn (*P. japonicus*) sector. Recently two other species (the banana prawn *P. merguiensis* and the brown tiger prawn *P. esculentus*) have been tested to help the industry diversify and to meet postlarval shortfalls.

Strict environmental controls and coastal zone management practices prevent the kind of more rapid development seen in SE Asia, but also ensure that the environmental degradation and disease issues that have caused some spectacular crashes in these Asian industries will not be repeated in Australia. Environmental management and the rapid uptake of scientific advances in prawn production technology and disease control will ensure that Australian farmers have a small but competitive and sustainable portion of the world's prawn aquaculture.

Australian prawn farmers generally have agricultural backgrounds but increasingly farms employ key production staff, such as farm and hatchery managers, with tertiary training in intensive animal production or aquaculture.

Markets and marketing issues

Currently Australia grows two species of prawns: the black tiger prawn, *Penaeus monodon*, and the Japanese king or kuruma prawn, *P. japonicus*. The black tiger prawn is mostly sold on local Brisbane, Sydney and Melbourne markets, either fresh, frozen or cooked. The kuruma prawn is grown exclusively for live shipment to the markets of Japan, principally Tokyo and Osaka.

Most growers develop their own processing facilities and distribute their own product. The industry could be better served by having co-operative regional processing plants, or by integrating with the capture-industry processors. Average processing and marketing costs range between $1.39 and $2.50/kg.

Most farmers are harvesting, processing and shipping direct to markets, without elaborate chains of agents and middlemen. Shortage of space for this perishable commodity in jet cargoes has been a limiting factor at times in the industry's development, especially at key production times. Access to international airports is critical for site location and marketing.

Key statistics

Queensland's production and value statistics are used to describe the trends in the Australian industry. In 1995, Queensland had 20 farms, NSW 6, Northern Territory 1. Statistics for 1994 are the most recent compiled by the United Nations Food and Agriculture Organization for the global summaries.

Queensland — Production (t):		
Species:	**1991–92**	**1995–96**
black tiger	710	1104
kuruma	0	190
Total	710	1294
Global	822,700	920,617[a]
Queensland — Value ($AUSm):		
Species:	**1991–92**	**1995–96**
black tiger	8.5	14.8
kuruma	0	13.4
Total	8.5	28.2
Global (US$m)	5,213	6,328[a]

[a]1994

Prices of course vary widely because of market demand, exchange rates, and the form and quality of the product. However, as a guide, black tiger prawns sold (ex farm-gate) for $11.00–15.50/kg (average $13.41) in 1995–96 on Australian markets, while kuruma prawns sold (landed live in Tokyo) for $50 to 150/kg. The average price for kuruma prawns dropped from $84.50 in 1994–95 to $70.70 in 1995–96 because of the strengthening Australian dollar against the yen.

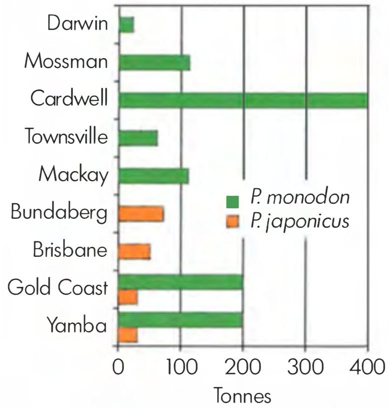
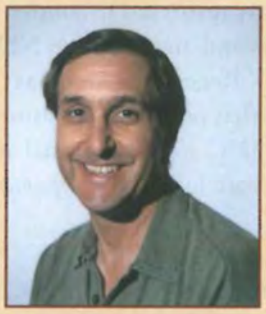


Figure 1. Production levels (1996, tonnes) of the black tiger prawn (*Penaeus monodon*) and the kuruma prawn (*P. japonicus*) in eastern Australia.

Black tiger prawns, *Penaeus monodon*.

About the author



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Production requirements

The black tiger prawn is the most popular and widespread species in cultivation from northern NSW to north Queensland and into the Northern Territory. There is also a proposal for a large farm on Exmouth Gulf in Western Australia. In the southern part of its range, temperatures restrict the growing season to one crop per season, while in the north there is potentially a nine-month growing season (at temperatures above 23°C). However, because of shortages of postlarvae and some viral diseases, the number of crops in north Queensland farms has dropped from 1.17 to 1.04 crops per pond per year.

The kuruma prawn production is currently restricted to southern Queensland and northern NSW (Fig. 1). Recent research has shown that pond temperatures above 32°C are sub-optimal and at 36°C are lethal to *P. japonicus*.

Australian prawn farms are restricted to the coastal zone, virtually all drawing their intake water from tidal creeks and estuaries. Early farms were built in mangroves, but acid sulfate soils have proven unsuitable. Modern farms are behind the mangrove fringe on salt flats or converted cane farms. Unfortunately, most hatcheries are located in similar locations. Water quality and salinity requirements for raising larvae are higher than for adults; poor water quality and attendant diseases have led to intermittent failures in larval and postlarval production.

A recent study by CSIRO, using Geographic Information System (GIS) technology, has shown that less than 4% of available land in the Logan River area of southeast Queensland is optimal for prawn farming when soil type, vegetation, slope and elevation, proximity to water and urban areas are taken into account. GIS offers a powerful tool for site selection by prospective farmers and coastal zone managers to aid the development of coastal aquaculture.

Key statistics

- In 1993–94 prawn aquaculture production was valued at $21.1 m.
- Prawn aquaculture has expanded 1600% in the last four years (1400 t) but is still only about 7% of Australian prawn production (21,600 t).
- Prawn exports valued were valued at $206m in 1994–95.
- Australia imports 13,000 t/year of low value prawns.

Varieties/breeds

The black tiger prawn (*P. monodon*) is by far the most popular species grown in Australia and southeast Asia. Its very rapid growth rates and its low requirement for protein make it an attractive species for aquaculture. Ironically, in the wild, in most parts of its Indo-Pacific range, it is rare to uncommon, leading to chronic and at times, acute shortages of spawning stock and postlarvae. There is intensive world-wide research to domesticate this species to alleviate the reliance on scarce wild broodstock and take advantage of selective breeding.

The kuruma prawn (*P. japonicus*), while less commonly produced, is fast catching *P. monodon* in value. It too has a very wide range in the wild, but spawners only occur predictably in a few locations off central Queensland. This species has recently been domesticated and selective breeding trials have begun in southeast Queensland.

Recently two other species (the banana prawn *P. merguiensis* and the brown tiger prawn *P. esculentus*) have been tested to help meet postlarval shortfalls and allow the industry greater scope for diversification in growing areas and markets.

Fish husbandry

Site selection is probably the most important element in getting started. Physical location (soil, slope, access to salt and freshwater, tidal range, rainfall and runoff) are all very important. All too often in the past, the growing requirements, especially temperature and salinity optima, of the species have not been carefully examined. Noting subtle differences in optima, not just lethal ranges, can mean the difference between one and two crops per year, or finding which species is best suited to a particular location.

Broadcast prawn feeder with air blower

Key messages

- Growth of the industry will be limited by suitable sites.
- Increased productivity is possible through better husbandry and domestication.
- Diseases can be minimised with better diagnostic tools and environmental management.
- Better management will ensure sustainability.

More importantly, a careful examination of markets must be undertaken. Here again the species choice, size and form (live, fresh, frozen, cooked) of the product can dictate the location, production strategy and infra-structure needs (e.g. proximity to hatcheries, processing plants, domestic or international airports).

In Australia all prawn production is done in earthen ponds, close to tidal sources of seawater. The pond bottoms have a clay base for retaining seawater. Site elevation and tidal range have to be considered, to minimise pumping costs and maximise the options for water exchange.

The key to good culture and husbandry practices is being able to maintain water quality close to the species' growth optima. Often, sites are compromised by intermittent or prolonged periods of low salinity because of poor tidal exchange or rainy season flooding. Stocking densities, food quality and feeding regimes will also influence growth rates and effluent quality. Farms are beginning to experiment with closed system (partial to full recycling) culture methods to maintain water quality and isolate the farm from the vagaries of external water supplies, as well as to comply with increasingly stringent discharge requirements. Effluent treatment, using marine plants and animals as alternative crops, is also being explored in open and closed systems.

Several manuals on production techniques are available and advice is available from extension officers in all States.

Depending on location (and consequent temperature regime) and market strategy, crops of both species can be brought to harvest in 5 to 9 months from stocking postlarvae. Southern locations only get one crop per year, northern farms are in production year-round, but do not yet get two crops per year. Potentially, species rotation would allow double cropping.

Pest and disease control

All animals grown intensively, under artificially high densities, are prone to disease. Prawn aquaculture is no exception with bacterial, viral and parasitic diseases affecting all life history stages and production phases from hatchery to grow-out. Most bacterial and parasitic diseases are easily identified and treated with better hygiene and limited use of therapeutants.

A more insidious and serious threat to the industry is viral disease. The industries in Ecuador, China and southeast Asia have had some catastrophic collapses caused by environmental degradation and/or attendant viral diseases. The relationship between environmental factors and the outbreaks of the causative agents is not well understood.

Australia has only recently been affected by some viral diseases, especially among black tiger prawns in north Queensland. These diseases are new to science, not well characterised and their etiology and epidemiology are poorly understood. Remedial action with pond dry-outs, liming and chlorination seems to be effective, but does not guarantee against re-occurrence. More research into the environmental conditions that predispose prawns to disease (environmental stresses), and the development of diagnostic tools to identify the causative agents and trace their epidemiology are necessary.

The long-term aim is a suite of techniques including diagnostics, vaccines and/or selectively bred strains that are resistant to a variety of viral pathogens. In the meantime, better husbandry practices including ensuring high water-quality standards, lower stocking densities, and the screening of spawners and postlarvae will minimise the occurrence and spread of these viral diseases.

Harvesting and postharvest handling

Harvesting and postharvest treatments are dictated by the species and marketing strategy. Typically black tiger prawns are harvested en-masse with a drain harvest, chilled or cooked on site and shipped to domestic markets. More selective harvests by prawn size or in smaller quantities are undertaken to meet market requirements. Seasonal demands and peaks in prices (e.g. Christmas holiday periods) are often production targets. Alternatively, a steady supply of a certain size of prawn may satisfy other specialist markets such as wholesalers and restaurants.

The kuruma prawn is grown exclusively for the live trade to Japan. Smaller quantities are harvested several nights per week to coincide with market demands and/or air-cargo space and schedules. The animals are chilled and packed in moist sawdust to keep them torpid during transport and timed to emerge actively from the shipping containers. Details about the techniques can be obtained from QDPI. The price paid in Tokyo is based on survival rates, physical appearance and level of activity. Here too prices vary widely according to supply and demand, seasonal spikes at festival times and the quality of the product. Australia is gaining a reputation for high-quality kuruma prawns but cannot yet get the premium price paid for Japanese product, because of either a real need for further quality improvement or of cultural distinctions.

Japanese king or kuruma prawn, *Penaeus japonicus*

Economics of production processing

Costs of production. Most growers' costs of production, excluding processing and marketing costs, depreciation and financing range between $7.50 and $9.00/kg, depending on the scale of the operation. The average production cost per kg is $8.27 (Table 1).

Table 1. Percentage costs of production

Prawn feed	37.0%
Wages and salaries	25.6%
Electricity	6.6%
Larvae (stock)	10.1%
Fertiliser & chemicals	1.5%
Repairs & maintenance	10.2%
Freight costs	3.4%
Licences and administration	3.0%
Miscellaneous	2.6%

Cast net sampling of prawns during grow out

Profitability (analysis by Paul Thomas, Shrimptec P/L)

Assumptions:

a) Average production/ha/year 5000 kg

b) Average cost of production/kg $8.27

c) Average processing/marketing costs/kg $2.12

d) Average sale price $14.50

The gross profit/ha on an average production would be $31,150 (42.9%), with a net profit of $20,000/ha/year or 27.5% excluding depreciation and borrowing costs.

Capital costs. To develop a farm fully with all appropriate equipment, ponds, buildings, including processing facilities will cost anywhere between $20,000 and $60,000/ha (pond), not including land costs. These costs vary with site selection and depend on proximity to local infrastructure, site topography, vegetation and seawater access. The major cost will be the installation of an electricity network through the farm. It is difficult to say what is the optimum sized operation, but family-operated farms of 10–20 ha can be very profitable, with corporate operations looking for operations greater than 50 ha to become economical.

The cost of applying for an environmental licence is between $5000 for small (< 5 ha) to $60,000+ for large farms (> 50 ha). Once approval has been given, the annual environmental licence costs (Qld current costs) are up to $3000/year for farms greater than 20 ha.

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Redclaw crayfish

Clive M. Jones

Introduction

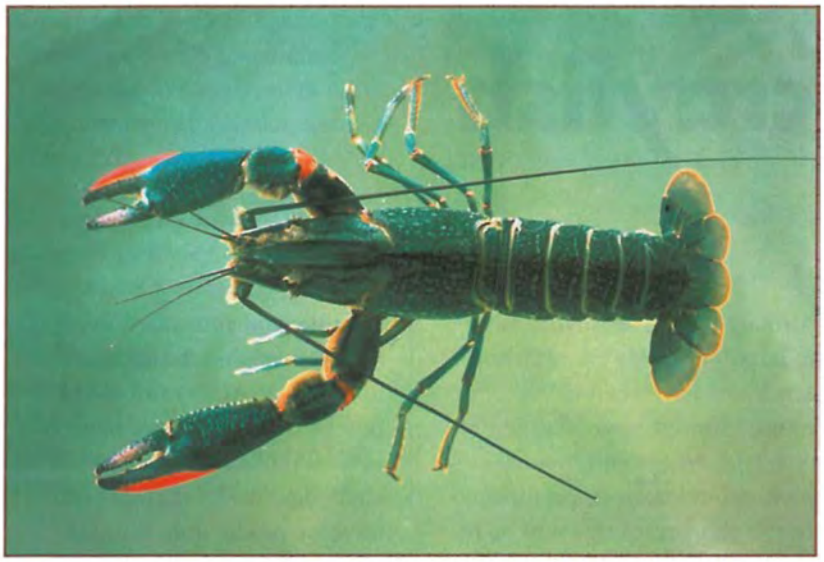
Redclaw, *Cherax quadricarinatus*, is a species of freshwater crayfish native to the rivers of north-west Queensland and the Northern Territory. Although well known to the locals of this isolated region of tropical Australia, it remained effectively unknown to the rest of Australia until the late 1980s.

Redclaw is advantaged by a host of physical, biological and commercial attributes which make it an excellent candidate for aquaculture. It is a robust species with broad geographic potential, has a simple life-cycle and straight-forward production technology, requires simple foods and is economic to produce. The texture and flavour of the flesh compares very favourably with other commonly eaten marine crustaceans, and because it looks like a lobster, it is positioned at the premium end of the crustacean market spectrum.

While current production at around 60 t/year is primarily marketed domestically, the growth potential for the industry lies with the substantial export demand for this product.

Although a native Australian, redclaw's excellent aquaculture attributes have seen it transplanted to several other countries where commercial production has been established. In the short-term this will be to Australia's advantage in increasing the market profile of this new product. Longer term, Australia will maintain a production advantage based on access to the broad genetic pool of native stocks, sustainability due to thorough environmental regulations, and isolation from recognised diseases which have decimated off-shore industries.

Redclaw aquaculture in Australia is poised for significant expansion. The basic resources of suitable land and water are readily available throughout northern Australia, and could potentially support production of several thousands of tonnes. The challenge for the industry is to increase production, through expansion and new investment, so as to lift production volumes to a point where the substantial quantities required by identified export markets can be consistently supplied. Production technologies, while still being developed, are at a stage where 'best practice' methods have been identified. These technologies are relatively straight-forward and the skill levels required of practitioners are not onerous. Supporting documentation and training are readily available.



Mature male redclaw crayfish have distinctive red patches on their claws.

Markets and marketing issues

The redclaw industry is faced with several marketing challenges. Typical of most fledgling industries, very little promotion has been done, thus consumer awareness both domestically and overseas is relatively low. The industry is composed of many small enterprises making the marketing quite fragmented. Recently, localised marketing groups have emerged, consisting of several cooperative growers with common purpose. They have established quality standards, brand names and promotional material to more effectively market their collective production in a coordinated manner.

In Australia, redclaw are commonly marketed in 20 g size grades ranging from 30–50 g (at approximately $11.50/kg) to greater than 120 g (at approximately $19.00/kg). The smaller grades are commonly used in buffet style presentations, with the larger animals featuring in à la carte restaurants, both as entree and main course dishes. Export opportunities have been identified through considerable market research. However, sales to date have been limited by the small production volume and therefore the risk of inconsistent supply. At present 60% of redclaw are sold within Queensland, 10% interstate and 30% are exported.

There are three steps in the marketing chain; producer, wholesaler and restaurateur. There is effectively no retail sale of the raw product. While selling direct to restaurants may result in slightly higher prices paid, the practice can have a limiting effect on market growth. A good wholesaler can increase the market penetration of redclaw by cross-selling while servicing customers from their existing product lists. Farm-gate sales are substantial, but the volumes are likely to decrease as more coordinated marketing through wholesalers develops.

Wholesalers have tended to position redclaw on the price scale lower than marine lobsters but higher than prawns. They are generally marketed alongside Moreton Bay bugs and small champagne lobsters or scampi.

A clear marketing attribute for redclaw is its reputation as a product from clean water, free of medical or chemical additives. Product is purged before sale and is often held in salt water which improves the flavour and its attractiveness to Asian markets.

About the author

Clive Jones (BSc PhD) is a Principal Biologist Aquaculture at the Freshwater Fisheries and Aquaculture Centre Walkamin (see *Key contacts* for address) and has been involved with redclaw crayfish since 1988. His work has proved to be a stimulus to wide interest and commercial development in redclaw aquaculture. He spent two years in industry and has studied crayfish farming techniques in the United States and Europe. Since 1992 he has supervised a research program developing production technologies for redclaw. He is widely recognised in Australia and throughout the world as the leading expert in redclaw aquaculture.

Redclaw are largely sold as a live product, although some processing is done, particularly cooking and freezing. Fresh redclaw have a smooth, lustrous, deep blue to green shell,, with males exhibiting a bright red colouring on the margins of their large claws. Cooked, they present as bright red, typical of premium crustaceans.

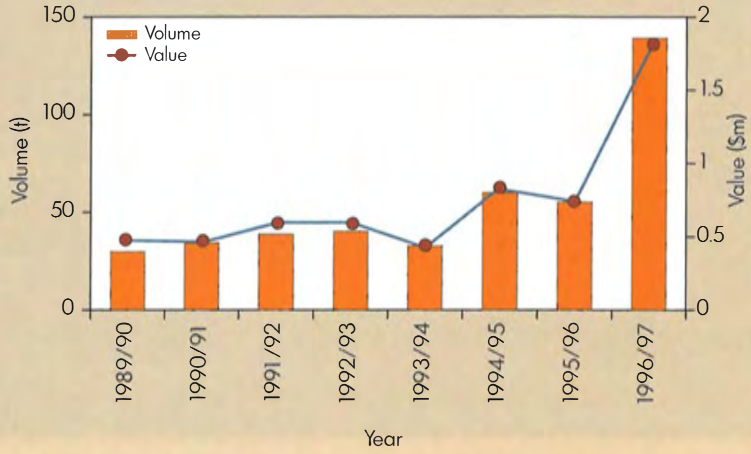
Production requirements

Redclaw is a tropical species endemic to north-west Queensland and the north-east of the Northern Territory. The harsh physical extremes of this region mean that redclaw has evolved as a robust animal with broad climatic tolerances. Its preferred water temperature range for >70% of maximum growth rate is 23–31°C. Redclaw will die at temperatures below 10°C or above 36°C. Reproduction will occur only while water temperature remains above 23°C. While suitable temperatures prevail throughout Queensland during summer, the shorter and less extreme winter period in more northern areas confers a significant advantage. Most industry growth is expected to occur north of Bundaberg, including parts of western Queensland, the north of the Northern Territory and the Kununurra region of Western Australia. The accompanying map broadly indicates the regions suitable for redclaw production.

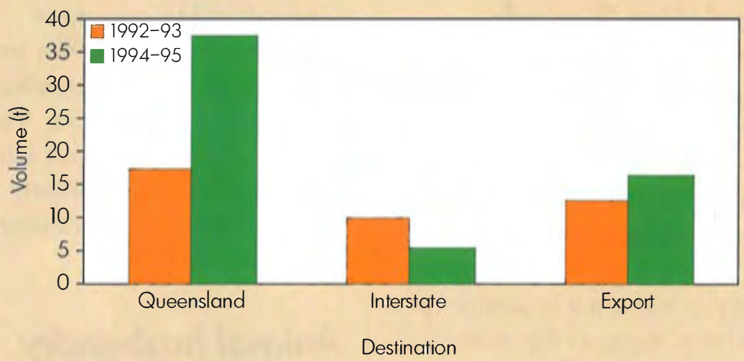
Redclaw aquaculture needs earthen ponds which will hold water. Consequently, the soil must have a reasonable clay content and be free of rock. Ponds are typically 1000 m^2 in surface area, with a depth of between 1.0 and 2.5 m. Their specification and design can have an important bearing on productivity, so professional advice should be sought before construction. Productive topsoil can be beneficial when applied across the clay-base of a pond, but it must be free of pesticides which may be highly toxic to crayfish. Some practitioners recommend lining of ponds with coarse river gravel to enhance productivity, but the benefit–cost of this practice has not been assessed.

Water may be sourced from surface supplies or underground. Generally, water suitable for watering livestock is suitable. Some of the characteristics which should be identified include: pH of between 6.5 and 8.0, hardness of > 40 ppm, low salt content and low metals content. Once water has been introduced to the production ponds there is a host of management issues which must be addressed to ensure optimal water quality for redclaw production. Further information on water quality management should be sought. Water usage is dependent on local evaporation rates, but will range from 15 to 20 ML/ha of ponds. This is on the basis that all effluent from harvested ponds is recycled through appropriate settlement and supply dams.

Key statistics



Redclaw crayfish production in Queensland. Figures for 1996/97 represent projections as estimated by industry sources.



Sales of Queensland redclaw by destination, 1992–1994.

North Queensland redclaw farm

Varieties/breeds

Research has demonstrated that distinct strains of redclaw occur throughout the species' natural range. The differences between strains are generally slight, but variability of biological characteristics, as borne out in production statistics, suggests that some strains may be superior for aquaculture. Although the full range of strains has not been assessed, it is clear that the Gilbert and Flinders River strains have advantageous characteristics in regard to high fecundity (no. of young per brood) and fast growth rates at high densities.

Some long-standing redclaw farmers have selectively bred their perceived 'best' crayfish and cross-bred strains to improve their stock. There are clear indications that these improved stocks are superior to wild, undomesticated stock, and to stock from farms where managed reproduction has not occurred.

A managed selection program for increased growth rate of redclaw was established by the Queensland Department of Primary Industries in 1993, and so far has successfully increased growth rate by about 9.5%. This program is continuing and will likely generate a significantly improved stock for distribution to industry by 1999.

Animal husbandry

Once all government approvals have been sought and an aquaculture licence has been issued, the farmer may acquire crayfish from established growers. It is recommended that a small number of broodstock be purchased and used to generate juveniles for stocking to the new operation.

The husbandry involved is best explained in terms of the key elements of recognised 'best practice'. Site selection is the first step, and should involve assessment of several criteria which will maximise the suitability of the chosen site. A designed and systematic farm layout is important to minimise establishment and operational costs by utilising gravity to fill and drain ponds, and to centralise facilities. Optimal pond specifications are 1000m^2, 1.2–2.5 m deep and a V-shape that allows rapid and complete drainage.

Artificial shelters for the crayfish are essential. They should be abundant, and their shape, specification and positioning should permit water to drain out freely and completely as the pond is drained. Thick bundles of synthetic mesh have been found to be the most effective.

Aeration is also essential. For redclaw aquaculture it is most often provided through airlift pumps, although other forms of aeration such as paddle-wheels and aspirators may be used. The aeration system should provide both oxygen input to the water and circulation of water from bottom to top and around the pond.

Key messages

- Established and proven production technology
- Attractive economics
- Excellent markets with high export demand
- Significant growth potential

Juvenile production and grow-out of stock to market size are managed as separate processes. A managed juvenile production program is essential to provide the advanced juveniles required for grow-out, and to make effective use of the superior broodstock selected. Depending on temperature and whether berried females or mature broodstock are used, a culture period of 3–4 months is necessary to achieve a mean size of juveniles of 5–15g. The two most critical factors in juvenile production are shelter and food.

Grow-out also involves an active stock management approach. Because redclaw breed so readily and profusely, the pond populations must be managed intensively. This includes stocking with known numbers of advanced juveniles of at least 5 g mean weight. Uniformity of size is very important. Maximum size range at stocking should be 10 g. A stocking density of between 5 and 15 per m^2 is recommended.

The food used will have an important bearing on production. Several commercial crayfish pellets are available, and they have proven to be effective. Chicken layer pellets are not recommended. The most effective diets have a protein content of approximately 20% and are composed primarily of grains. A feeding frequency of 3–5 times/week is adequate, but daily feeding is recommended, preferably at dusk when crayfish are active. Use of a feeding schedule is critical.

Active management of the pond environment is integral to commercial yields. There should be weekly monitoring of pH, dissolved oxygen and turbidity; and monthly monitoring of hardness, alkalinity and ammonia. All measurements must be made at the water/soil interface on the bottom, and some contingency plan must be developed to counter water quality which falls outside of preferred ranges. This may involve applications of lime or fertiliser, or flushing of the pond with fresh water.

Drying of ponds between crops is essential to sterilise and revitalise the bottom. There is often a considerable build-up of organic waste after a culture period. The most effective management of this is to dry the pond for 1–2 weeks until cracks appear. Toxic compounds are broken down and useful nutrients are released.

Protection against birds, rats, and eels, and any other potential predators must be provided. Complete enclosure by netting and fencing is essential. A recent economic analysis indicated that the cost of netting (including materials and installation) is equivalent to 15% of one optimal crop. As losses to predators may be well above this, netting is very cost-effective.

Provided good husbandry practices are applied, juvenile production and grow-out can be completed within 12 months.

Disease control

Several potentially serious disease-causing organisms including protozoans and viruses have been identified in redclaw. To date none has caused any significant commercial loss, and the industry is aware that careful quarantining and good health monitoring and management will minimise the risk of a disease outbreak.

A virulent disease of crayfish which has decimated production throughout Europe is known as 'crayfish plague'. Australia is free of this disease, and authorities are conscious of the importance of preventing its entry into the country.

By maintaining good culture conditions which maximise survival and growth, stress of crayfish is minimised and the threat of disease is relatively small. Because production of juveniles and grow-out are contained on each farm, there is little requirement to introduce

Newly harvested juveniles are graded before stocking into growout ponds.

new, potentially disease-carrying stock to the farm. This factor also diminishes the risk of disease.

Harvest, processing and packaging

Harvesting is generally quite straightforward, but if it is not managed carefully, the previous several months of production management can be wasted. Some form of sampling before harvest is important to gauge the size and number of crayfish expected. Harvesting may involve a number of methods, although the most effective is the application of a flow-trap. This trap exploits redclaw's strong response to flowing water. A slow but steady flow of water into the pond via a box and ramp will illicit movement of crayfish against the flow and into the box.

Flow-trapping should involve 95% drainage of the pond over 24 hours from dawn to dawn. There should be several thousand litres of water remaining in the deepest part of the pond at dawn, when stock are removed. The slow drainage enables the crayfish to move out of shelters and with the main body of water, so they concentrate and respond most effectively to the flow trap. Both the flow trap and the last remaining water must be well aerated. The entire harvest can be easily lost if the flow trap or remaining pond water are not aerated. The stock should be quickly removed and transported to clean water in a tank system. Care should be taken to minimise crushing by not exceeding 15 kg of stock per transport container.

Other harvesting methods include bait trapping and drain harvesting with manual collection of stock.

Most redclaw are sold live, and so after harvesting stock are held in tanks with flow-through water supply or a recirculating system involving biological filtration. A stay of at least 24 hours in the tank to permit purging of the gut is recommended before packing for transport. Redclaw can survive extended periods out of water provided they are kept cool and moist. Packing therefore involves insulated containers containing some moist packing material (foam rubber or wood shavings) and cooling packs.

Road transport is used to reach local markets, but air transport is necessary to supply the large seafood markets in Sydney, Melbourne and for export.

Economics of production

The profitability of redclaw aquaculture has been assessed using a model or hypothetical farm, with data gathered from two, pilot-scale commercial farms established jointly by the participating farmer and QDPI. The model involves a farm size of 40×1000 m^2 grow-out ponds and 7×1000 m^2 juvenile production ponds, representing a total pond area of 4.7 ha. Previous analysis suggested that a production area of approximately 4 ha was the minimum for commercial viability.

The financial evaluation was undertaken using a discounted cash flow technique. Discounting was used to allow for the timing of the costs and benefits for the life of the enterprise, which was assumed to be 20 years.

The model farm was assumed to harvest 394 kg/year of redclaw per grow-out pond from year two onwards. Redclaw were estimated to take nine months to reach the acceptable market size of 65 g mean weight. At this weight the farm-gate price was estimated to be $13.50/kg.

Initial establishment of the model farm was estimated to cost $347,900. Included in this cost were land, hired labour, machinery and all farm infrastructure costs. Specifications for the farm layout and pond characteristics were based on 'best practice' recommendations.

Redclaw aquaculture was profitable based on the model farm. Using the model farm yield and price, the farm profit was $5.25/kg/year. The total costs of production were estimated to be $8.25/kg/year. Included in this cost were all operating costs, capital costs and allowance for the owner's labour and management. The discounted payback period, which represents the time to recover the initial outlay, was 4 years.

Sensitivity analyses for prices and yield showed that, at the annual yield of 394 kg/ grow-out pond, the minimum price for the investment to be profitable was $8.25/kg. Similarly, at the assumed price of $13.50/kg, the minimum annual yield required to be profitable was 232 kg/ grow-out pond.

Grow-out periods may vary between 6 and 15 months depending on the redclaw market weight the grower intends selling. Redclaw market weights and price were assumed to increase with longer turn-off periods. Based on a sensitivity analysis which compared various grow-out periods, the most profitable option was 9 months. The least profitable turn-off period was 12 months. The results from this analysis were very sensitive to prices, survival rates and market weights. Survival rates and market weights are strongly correlated to farm management expertise.

Results from established farms applying best practice techniques confirm that the economics of the model are a true and accurate representation of commercial redclaw aquaculture.

Key contacts

For further information on redclaw aquaculture contact the extension officers at the following QDPI centres:

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Silver perch

Stuart J. Rowland

Introduction

The silver perch, *Bidyanus bidyanus* (Mitchell), is an Australian native freshwater fish that is endemic to the Murray–Darling river system. It was commonly used as food by Aborigines, but is now uncommon in the wild.

Hatchery techniques for silver perch were established by the early 1980s. Research at the NSW Fisheries' Grafton Research Centre since 1990, has demonstrated that silver perch is an excellent species for culture in earthen ponds. High survival (> 90%), fast growth rates (2–3 g/fish/day) to market-size (caµ 500 g) at high stocking densities (20,000 fish/ha) lead to high production rates (10 t/ha/year), with relatively low feed costs ($1.00/kg of fish). Silver perch has the potential to form a large industry (> 10,000 t/year) based on high-volume, low-cost production.

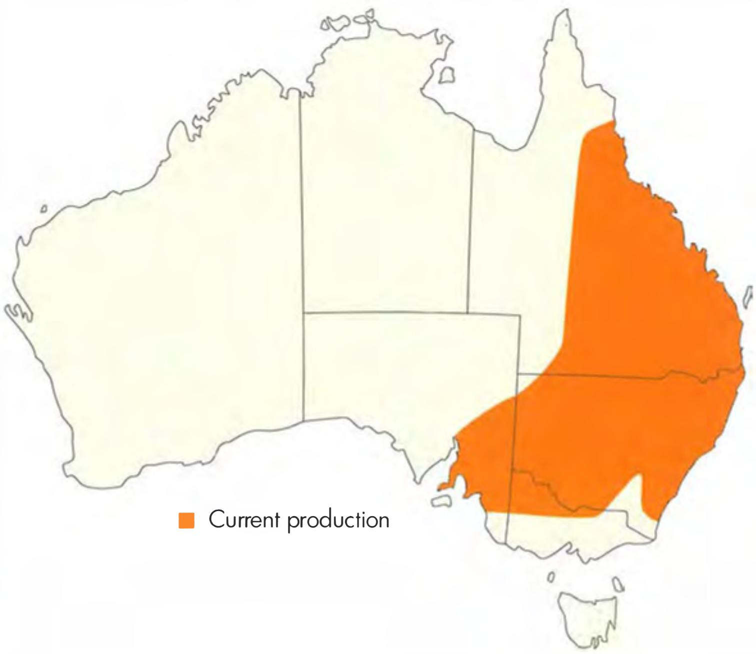
The major challenges for the industry are to reduce feeding and production costs, to develop efficient farms using good aquaculture practices, to develop and implement a quality control program and to establish a processing component leading to the supply of silver perch in a consumer-friendly form with an effective marketing campaign.

Markets and marketing issues

Silver perch is a premium quality fish, which has a mild flavour, moist, white flesh, with very few bones and a high meat recovery of 40%. Like all freshwater fish, it can develop a 'muddy' taste or 'off' flavour from the pond environment, and so needs to be purged after harvest.

Silver perch are marketed in the live-fish trade which serves mainly Asian restaurants in Sydney and Brisbane. Prices to the grower are $10–15/kg, and the fish retail for $20–45/kg. This relatively small but lucrative market is expected to increase as Asian communities in Australia grow, and the demand for high-quality, fresh product increases across our society.

Some farmed silver perch are sent whole and chilled to the Sydney Fish Markets where they can bring $5–13/kg at auction, depending on presentation, quality and daily market fluctuations. Several farmers are developing local markets in clubs, hotels and restaurants. There appears to be much scope for local marketing in inland regions where silver perch is well known and regarded, and where there is a shortage of fresh fish.



Large-scale marketing and promotion of silver perch have not yet been undertaken because of the present limited supply of the fish.

By far the largest market available is the domestic market for processed product e.g. fresh fillets; frozen, and packaged fillets. Much of the fish eaten in Australia is in this category, and most of it is imported. The great potential for development of the silver perch industry is in replacing some of the fish sold through retail outlets, supermarkets, clubs, hotels, plus that provided in institutions such as hospitals, nursing homes, military bases and so on, with farmed silver perch. Processing increases product types, greatly expands market niches, and will enable the clear delineation of farmed fish from wild-caught fish. The latter is important because of the growing consumer concerns about the increasing pollution of estuaries and the marine environment, both in Australia and overseas, and the subsequent effects on the quality of seafood.

The number of farms and the production of silver perch have now reached levels that guarantee increasing availability and continuity of supply. Markets outside the niche live-fish trade can now be developed and the species promoted to a wider range of consumers.

Production requirements

Silver perch is a temperate, warm-water species that can tolerate water temperatures of 2° to 38°C. Although it can live over a wide area of Australia, optimum water temperatures for growth are between 20° and 30°C. The length of the growing season, and therefore the time taken to reach market size, will be determined by the temperature regime. Regions with a growing season (> 20°C) of at least 5 months, preferably 7 or 8 months, are most suitable for the commercial aquaculture of silver perch. This excludes much of Victoria and the southern tableland areas of NSW. Successful farms are located from the Murray River to northern Queensland.

About the author

Stuart J. Rowland BA (Hons), PhD has been conducting research into the taxonomy, biology and aquaculture of native fishes for over 20 years. He developed techniques for the artificial breeding of Murray cod, golden perch, silver perch and the endangered eastern freshwater cod, and for the husbandry and intensive pond culture of silver perch. See *Key contacts* for author's address.

Silver perch, *Bidyanus bidyanus*, an attractive schooling fish. These silver perch (500–700 g) were harvested from a pond at the NSW Fisheries' Grafton Research Centre.

Site selection is the first and most critical step in establishing an aquaculture facility. An abundant supply of good quality water is essential. Large, permanent rivers and creeks are most commonly used, and underground water is ideal, assuming the quality is acceptable. If rain run-off is to be used as the main supply, water budget and storage requirements must be closely estimated. Domestic water supplies should be avoided because of the limited supply, high cost and chlorine and ammonia content.

An experimental freshwater aquaculture facility has been established at the Grafton Research Centre. Water is pumped from the Clarence River to two earthen reservoirs (capacity 17.5 ML) from where it is gravity fed to the 19 ponds (15 @ 0.1 ha; 4 @ 0.3 ha) and buildings; effluent water from all facilities drains into an effluent/ settlement dam (43 ML) from where it is re-used by pumping to the reservoirs or stored for irrigation of pastures and crops. The NSW Fisheries' Silver Perch Aquaculture Policy requires that no effluent water is released to natural waterways.

Ponds should be constructed from impervious soils to eliminate or reduce the loss of water by seepage. Clay or clay-loams are ideal. Ponds should be 0.1 to 0.5 ha surface area, and those larger than 0.1-ha should be rectangular. The bottom should slope evenly to the deep section (2.5 m) which may contain a harvest sump. Each pond should have an inlet and a screened outlet structure, and should be completely drainable by gravity. Banks should be wide enough to ensure strength, stability and vehicular access. Electricity should be available for the aeration of each pond. Fingerling ponds should be netted or covered with wire to prevent predation by cormorants. A building(s) containing an office, laboratory, quarantine/ purging tanks, equipment and work area is also an essential part of a fish farm.

Varieties

All research, hatchery production and grow-out of silver perch to date has used the progeny of 'wild' broodfish, originally collected from the Murray–Darling river system. There has been no artificial selection. Recent research has identified several distinct genetic stocks or 'strains' of silver perch, and a selective breeding program is now under way at the Grafton Research Centre using fish from these stocks. These silver perch have been made available to industry for use as future broodfish.

NSW Fisheries' Grafton Research Centre

Key statistics

NSW production (t)	
1992–93	2.6
1993–94	4.5
1994–95	17.3
1995–96	28.8
1996–97	80.0

Fish husbandry

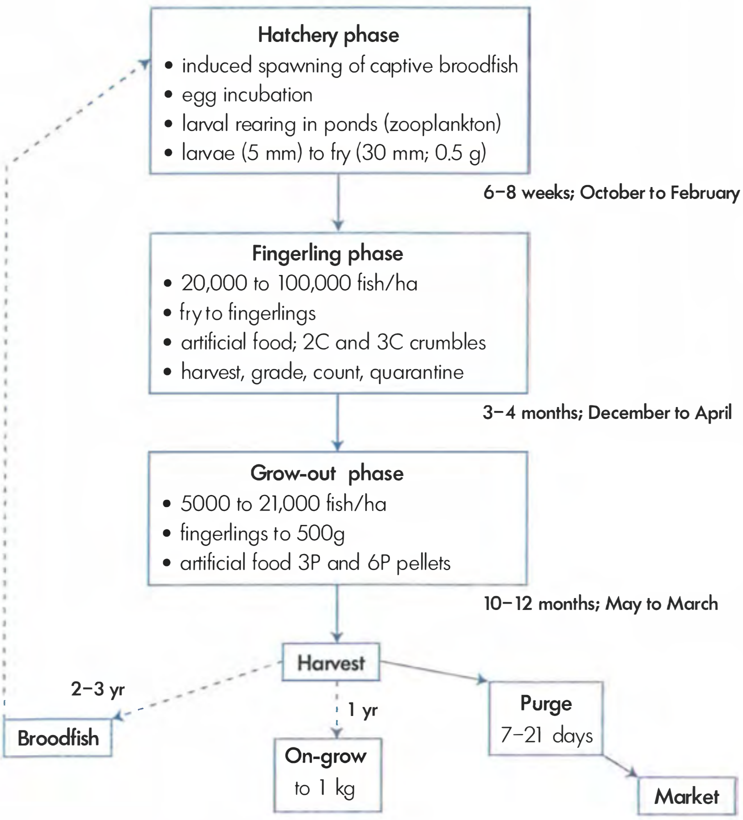
A three-phase production strategy is recommended for the pond culture of silver perch: I – Hatchery; II – Fingerling; III – Grow-out. This strategy, combined with a single-batch system where each pond has only fish of the same age or batch, which are harvested completely before the next batch is stocked, contributes to good aquaculture practice. The three-phase production strategy, however, is not rigid and there is scope for flexibility to suit each farm according to its facilities and production potential, and to enable continuity of supply to markets.

Some farms are involved in only one or two of the phases. A hatchery is a specialised operation requiring broodfish, spawning and incubation facilities, larval rearing ponds, and a relatively high level of technical expertise. Farmers can either purchase fry from a hatchery and then use Phases II and III to rear fingerlings, then market-size fish, or purchase fingerlings only and grow these out to 500 g. In cooler regions, where there are relatively short growing seasons, it would be an advantage to stock, in early spring, large (50–100 g) fingerlings that could be reared to 500 g by the end of the growing season in March.

Ponds are prepared by drying, removal of excess organic matter, and in some cases tilling to provide the basis for optimum water quality and fish health. Fish are quarantined in tanks before stocking, to reduce stress and to ensure they are free of disease. Recommended stocking rates are 20,000–100,000 fish/ha in the fingerling phase and 5,000–21,000/ha in the grow-out phase. Grading is necessary after the fingerling phase because a large size-range develops irrespective of stocking density. Silver perch reach a mean weight of ca 500 g in 15 months from spawning, and fingerlings (15 g) stocked in May reach 500 g in 10 months. Annual production rates up to 10 tonnes/ha have been achieved in static ponds at the Grafton Research Centre. Research to date suggests that although silver perch survive and feed well in cages and tanks, growth rates are slower than fish cultured in ponds.

Silver perch are fed a formulated diet containing 35% protein and made up of meatmeal, field peas, canola, peanut meal and lupins, plus a small amount of imported fish meal. Fingerlings are fed up to 7.5% and larger fish to 3% body weight per day. Food conversion ratios (FCR – weight of food fed: gain in wet weight of fish) of 1.2:1 for fingerlings and 1.5:1 during grow-out are now readily achieved using good quality feeds, appropriate feeding regimes, and by maintaining good water quality and fish health. Nutritional research by NSW Fisheries scientists has resulted in a lowering of the cost of feed from about $1,000 to $750/t; the cost of feeding silver perch is now around $1.00/kg of fish. Future improvements in the formulation and quality of diets, and feeding strategies should see a further decrease in the cost of feeding silver perch, hence a lowering of overall production costs.

Production phases and strategies



Production phases for the pond culture of silver perch

Key messages

- Silver perch-farm-raised, grain-fed, purged-fish for healthy living.
- Silver perch aquaculture industry: integration of hatcheries, grow-out farms, feedmills, fish transporters, processors, marketing.
- Silver perch-sustainable, environmentally-sound aquaculture.
- Research, extension, education.
- Silver perch: high-volume, low-cost production.
- Silver perch an Australian endemic freshwater fish.

Fish are sampled monthly from each pond using a seine net, to determine the mean weight, estimate the biomass of fish in the pond and to adjust the daily ration accordingly. Several fish are also examined for disease.

Although silver perch is a hardy species, successful aquaculture depends on the maintenance of good water quality. Temperature, dissolved oxygen concentration, pH, total ammonia and union-ised ammonia are monitored two or thee times a week because they can change from acceptable to stressful or lethal levels within several days, particularly during warmer months. The main techniques used to manage water quality are aeration, water exchange, regulation of feeding and stocking density, and the drying of ponds between crops. Dissolved oxygen is the most critical variable and aeration of ponds is essential in semi-intensive and intensive aquaculture. Silver perch ponds are aerated for at least 6 hours nightly (0200–0800h) usually with electrically-powered paddlewheel aerators at a rate of 6–10 hp/ha.

Pest and disease control

The diseases of silver perch are well known, and techniques for the diagnosis and treatment have been developed and can be readily implemented on farms. The major ectoparasitic diseases and the pathogens are: white spot, *Ichthyophthirius multifiliis;* chilodonelliasis, *Chilodonella hexasticha;* trichodiniasis, *Trichodina* sp.; ichthyobodiasis, *Ichthyobodo nectator*. Fungal diseases are: fungus or cotton-wool disease, *Saprolegnia* sp.; Epizootic Ulcerative Syndrome (EUS) or red spot, *Aphonomyces* sp. The major bacterial diseases and pathogens are: tail rot, *Flexibacter* sp. and/or *Aeromonas* sp.; columnaris, *Flexibacter columnaris* and Goldfish Ulcer Disease (GUD), *Aeromonas salmonicida*.

Rapid diagnosis of most diseases can be made on site using a high-powered microscope. The incidence of disease is much lower on well designed and managed farms, and the following factors contribute to a health management program; a suitable site with a good water supply and facilities; purchase of disease-free fish; use of quarantine procedures; appropriate stocking densities; close observation of fish during feeding; maintenance of good water quality; regular disease checks; careful harvesting and handling; and the drying of ponds between crops.

Harvesting silver perch fingerlings, Grafton

Harvest, handling and postharvest treatments

Silver perch are partially harvested using a seine net. Each pond is then drained and the remaining fish concentrated in an internal or external sump. Fish are hand-netted into bins containing water and transported to on-site purging tanks. Mechanical harvesters such as fish pumps and pescalators are used on large farms. Silver perch need to be purged for one to three weeks to eliminate 'off' flavours. Underground, spring or domestic water should be used because surface waters may contain 'off'-flavour compounds. Salt (3–5 g/L) is added to the water to reduce stress, prevent fungal infection and kill ectoparasites. Fish are not fed during this period. Purging will ensure a high quality, uniform product, and so is essential even for fish not destined for the live market.

Silver perch are transported in enclosed, fibreglass tanks on trucks. The water is filtered and oxygenated. Although silver perch are now displayed live in many Asian restaurants, they can be killed humanely and rapidly by placing them in an ice slurry or by Ike Jime, in which case they are then packed on ice in polystyrene boxes, labelled and transported to market. As with all seafood, freshness, quality and presentation are vital for successful marketing.

Economics of production

The economics of farming silver perch have not been determined because of the infancy of the industry. Most farms are either under construction or have been built only in the last three years. Aquaculture is an intensive animal industry that requires substantial capital investment, labour input and operating costs. The profitability of silver perch farming will be sensitive to the stocking densities used, the selling price and the cost of feed.

The following figures are based on a business plan which includes all costs associated with the purchase of land and equipment, and construction of 10 ha of ponds. Estimated capital costs are $1 million. Annual costs (excluding depreciation) are $272,000 and $344,000, and the minimum selling prices required to achieve 6% return on investment are $6.80 and $4.30/kg at annual production levels of 50 and 80 tonnes respectively. The costs and minimum selling prices will be lower on farms with available land, infrastructure and equipment; and in the future as the costs of feed and fingerlings decrease, the advantages of genetic selection, higher stocking densities and improved feeding regimes are implemented, and farms in general become more efficient.

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Fingerlings harvested by seine net

Trout

Geoff J. Gooley

Introduction

The land-based farming of salmonid fishes in Australia has a relatively long history, dating back to 1864 when fertilised eggs of brown trout, *Salmo trutta*, were imported from England. Several other salmonid species including rainbow trout, *Oncorhynchus mykiss*, Atlantic salmon, *Salmo salar*, brook trout, *Salvelinus fontinalis*, and chinook salmon, *O. tshawytscha*, have since also been introduced from the northern hemisphere and are being farmed to varying degrees at government and private hatcheries in NSW, Victoria, Tasmania, South Australia and Western Australia.

Of the trout species being farmed, rainbow trout and brown trout are the most common. Brown trout are produced primarily for state-based stock enhancement programs, which form an integral part of freshwater recreational fisheries management in the cooler, upland catchments of NSW, Victoria and Tasmania. Rainbow trout are produced on a far bigger scale for human consumption, and to a lesser extent for recreational purposes, including stock enhancement of public and private waters and on-farm 'fish-out' operations.

Most land-based trout farms are on private property close to a natural waterway from which water is diverted through the farm before being discharged as effluent back into the same waterway. The matters of water diversion and effluent discharge are currently the subject of considerable debate between the commercial trout-farming industry and various state fisheries, water management bodies and environment protection authorities. Restrictions on water diversion and effluent discharge are regarded by the industry to be an impediment on increased production.

Environmental legislation in many states now prevents the discharge of aquatic effluent from some types of fish farms (e.g. native fish farms in NSW) back into the environment, or at least stipulates that effluent water quality has to be at least as good as that of the in-flow. Key parameters used to monitor water quality effluent include total nitrogen, total phosphorus, Biological Oxygen Demand, pH, dissolved oxygen, suspended solids and temperature.

About the author

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Markets and marketing issues

World salmonid aquaculture production, including land-based and sea production of trout and salmon, is about 717,000 t and worth approximately US$3.1 billion/year. Rainbow trout (mostly land-based) makes up about 43% by volume (t) and 34% by value of total world salmonid production (1993 estimates). The major trout-producing countries are the United Kingdom, Italy, Spain, France, Germany, Chile, Denmark and the USA. Land-based trout farming production in countries such as Spain and Italy is currently increasing at about 10% per annum.

The major aquaculture production of salmonids in Australia occurs in Tasmanian sea cages, with approximately 6,192 t of Atlantic salmon and approximately 490 t of rainbow trout (ocean trout) per annum worth over AUS$56 million and AUS$3.9 million respectively (1994/95 estimates). However, land-based trout farming is the biggest freshwater sector and second biggest finfish sector in the Australian aquaculture industry with about 2,000 t worth almost AUS$12.5 million (of mostly rainbow trout) produced annually (1994–95 estimates).

The upper table below summarises the number and estimates of annual production (1994–95, unless otherwise stated) of rainbow and brown trout for each state.

The range of existing Australian land-based farmed trout products, together with nominal/estimated wholesale unit prices (delivered) is shown in the lower table below.

Marketable sizes range from the smallest (entrée size) whole fish, approximately 210 g weight, to the largest fish at about 3.0 kg in weight. The most common size is 300–400 g for whole fish and about 100–200 g/portion for fillets.

State	No. of farms[a]	Species	Annual production		
			T	Hatchery[b]	$'000
NSW	32	rainbow brown	300[c] 0.9	700,000 64,000	› 1,500[c] 47
VIC	37	rainbow brown	1,600[c] nil	136,600 275,300	› 8,000[c] 240
TAS	7	rainbow brown	200 nil	88,000 322,000	1,560 452
S. Aust.	2	rainbow	35[c]	?	210[c]
W. Aust.	3	rainbow	40[c]	?	400[c]

[a] Approximately 90% of production comes from only eight farms; remaining farms operate primarily for tourism purposes
[b] Refers to numbers of fish produced for recreational fish stocking
[c] 1996–97 estimates

Products (domestic, unless otherwise stated)	Wholesale price (delivered) $/kg (unless otherwise stated)
Whole fish, gilled, gutted & fresh/frozen — various sizes	4.5–8
Whole smoked fish, gilled & gutted	7.5–8
Fresh/frozen fillets	7.5–10
Smoked fillets (hot/cold)	15–20
Smoked pates & mousses	8
Live juvenile fish (200–300 g, for stocking)	3.8–4
Fresh, frozen, smoked products — export	generally marginally below domestic prices

The wholesale/retail network for farmed trout usually involves the sale of the product by the farmer to a wholesaler, the fish market or to frozen food distributors, and then to retailers such as restaurants, supermarkets, and fish shops.

Key messages

- Consistent high quality product
- Local markets saturated
- Lower costs with high volume production
- Potential for value-adding and export
- Major environmental constraints

Hatchery production of juvenile fish (fry and yearlings) for recreational fish stocking in public and private waters is primarily carried out by government-owned hatcheries or by private hatcheries under contract to state governments. A number of hatcheries also sell fish direct to the public for stocking farm dams and also for stocking private waters for commercial 'fish-out' operations. Brown trout are mostly favoured for stocking flowing waters and rainbows for lakes, impoundments and farm dams.

Production requirements

Maintenance of optimal water quality, temperature and flow rates are critical to reducing stress on farmed fish and to achieving maximum growth and survival. Farmed trout require relatively large quantities of fresh, flowing, highly oxygenated water at temperatures ranging from a minimum of 5 to10°C to a maximum of 15 to 20°C (optimal 8–18°C). Dissolved oxygen levels in excess of 5 mg/L and temperatures between 8 and 18°C are preferred at typical commercial stocking densities of 10–20 kg fish/m^3 of water. Flow rates, without supplementary aeration and assuming dissolved oxygen levels at or near saturation (>80% saturation), should be about 5-10 L water/ second/t of fish.

Most farms operate a completely flow-through, single-pass system. In most cases the water supply is an adjacent stream which is diverted by gravity or pumped through the farm, with effluent being discharged back into the waterway downstream of the diversion point. In many farms, effluent is directed through a terminal, non-production pond with a relatively large surface-area-to-volume ratio, which enables some settlement of suspended solids (residual fish food, faeces and other wastes) before the effluent is discharged. During periods of low ambient flows in the supply stream, some re-use of water is achieved by pumping waste-water back into the supply.

To meet environmental concerns, farmers are now having to consider the implementation of some form of additional treatment of effluent to reduce the levels of suspended solids, nitrogen and phosphorus. Options include the retrofitting of settlement ponds and/or constructed wetlands (if not already present), mechanical removal of suspended solids through the use of rotating micro-screen drum filtration, and supplementary oxygenation of ponds, tanks and raceways through the use of mechanical aerators and oxygen generators.

To what extent any or all of these options are efficient, practical and cost-effective remains to be seen. Of recent years, the quality of locally produced trout feeds has

Production ponds for land-based trout farm in Victoria improved substantially, with less waste and increased FCRs. Current trends in trout-feed manufacturing, largely reflecting industry needs, are towards higher energy diets with lower phosphorus levels to increase cost-effective production and reduce environmental impact.

Holding and rearing facilities vary from farm to farm, including fibreglass, concrete and prefabricated swimming- pool tanks and concrete and/or earthen raceways and ponds. The most favoured grow-out facility consists of relatively small (0.05–0.1 ha surface area; 1.0-2.0 m deep) earthen ponds or raceways with concrete inlet and outlet structures. Netting over the ponds or raceways is sometimes used to keep birds off.

The requirements for fish-farming permits and associated costs, including for land-based trout farming, vary from state to state but generally include:

- local government planning approval and public health approval for processing facilities (if appropriate);
- AQIS approval for export facility;
- water supply diversion permit from relevant water authority (if accessing public waters);
- effluent discharge permit from relevant environment protection agency (if discharging back to public waters); and
- fish culture permit (allows commercial trading in aquaculture produce).

Varieties/breeds

Many farms maintain their own captive trout broodstock to supply their own or other farms, although some farms also collect 'wild' brown trout broodfish on an annual basis for recreational fishing and stock enhancement purposes. It is unclear whether there are any true, genetically discrete, 'wild' strains of trout in Australia, with the possible exception of Tasmania. Most brown and rainbow trout in natural waters in Tasmania are not derived from hatchery progeny but from natural recruitment, and are thought to have been geographically and reproductively isolated from more 'domesticated' stocks long enough for them to be considered genetically distinct. Wild strains of trout are particularly favoured for recreational fishing because they are thought to offer better sport.

The domesticated strains of trout used in land-based farming are mostly selected for fast growth and high survival under intensive grow-out conditions. Additionally, a domesticated rainbow trout strain is maintained in Western Australia which is purported to be temperature tolerant, and therefore more suited to warmer ambient climates. More recently the production of various hybrid, all female, and sterile, triploid (artificially induced; three sets of chromosomes) strains of rainbow trout have been developed for commercial farming purposes. These fish typically exhibit better flesh quality and condition, and relatively rapid and/or more prolonged growth to larger sizes than normal strains.

Farmed rainbow trout being harvested by fish pump and graded

Husbandry

Intensively-farmed trout are fed on commercially available (locally produced), dry pelleted (steam pressed or extruded), compound diets, specially formulated and sized for each production stage (viz., juvenile starter feeds, grow-out and broodstock conditioning). Feeds are distributed daily by hand or with commercially available autofeeders. Feed rations and feeding frequency vary with stocking densities, water temperature and the developmental stage of the fish.

Options for feed rates specifically include feeding to satiation (demand) and feeding according to set weights (as percentage of fish biomass). Australian industry standard Feed Conversion Ratios (FCRs) range between 1.2 and 1.8 (kg food/kg fish weight), and vary with species, developmental stage, feed quality, feeding regime (auto/manual, frequency of feeds etc), water quality and temperature, stocking density etc.

Growth rates for farmed trout vary according to much the same parameters as for FCRs, but on average range between 100 and 300 g after 12 months, 1500 and 2000 g after 2 years and 4000 and 6000 g (mature broodfish) after 3 years.

Spawning occurs annually during May–July for both rainbow and brown trout, with maturation occurring in response to temperature and photoperiod cues. Trout breeding involves the hand-stripping and dry fertilisation of ripe eggs and sperm from 2–4 year old mature fish held on site. Fertilised eggs are incubated in flow-through containers and hatch after approximately 6 to 9 weeks at temperatures of 5 to10°C. On average up to 1000 eggs/kg of fish weight are stripped per female, and survival to hatching is usually up to 80%. Overall survival, from eggs to harvest, is typically in the order of 60–80%. It should be noted that many farms (about 50%) do not maintain broodfish but simply purchase young-of-the year juveniles (e.g. 5 g fingerlings) from other farms for their annual production needs.

Many farms crowd fish at high densities and reduced feed rates to retard, or 'stunt' growth, so as to ensure a year-round supply of fish at a specific size to meet market requirements. As required, growth in these fish is enhanced through increased feeding and lowered density to bring them up to market size. Many farms also simply employ the latter strategy, without stunt growing, to 'finish fish off' to market size as required. In a typical annual production cycle, most farms need to have the capacity to hold approximately 40% of annual production, including progeny from two year classes.

AQIS approved processing of smoked rainbow trout

Pest and disease control

Most disease outbreaks in land-based trout farms are stress-related and caused by poor water quality (e.g. inadequate flows and/or aeration) and/or poor husbandry (e.g. inadequate feeding practices, excessive stocking density), often compounded by high ambient summer temperatures.

Key statistics

- World production of land-based, farmed rainbow trout exceeds 310,000 t/year, worth over US$1.03 billion (as at 1993).
- Land-based trout farming is the biggest freshwater sector in the Australian aquaculture industry with about 2000 t production worth AUS$12.5m/year (as at 1994–95)
- Market prices for human consumption range from AUS$5–20/kg for rainbow trout, depending on degree of value-adding.
- Production costs range from AUS$4–15/kg depending on degree of value-adding.

The most common disease pathogens are ecto-parasitic protozoa (e.g. *Ichthyothirius* sp., also known as white spot, and *Trichodina* sp.) which commonly occur during the months of the year when the water is warmer. Bacterial and viral pathogens are less common, although EHN virus, also known as redfin virus, is a stress-related, water-borne pathogen which has sometimes caused significant mortalities in some NSW and Victorian farms.

In most cases disease outbreaks are controlled by reducing stress levels (eg. through increased flow rates, supplementary aeration, reduced stocking densities etc) and in extreme cases by the use of chemical parasiticides and/or antibiotics. Apart from reducing the rate of infection through reduced stress, there is no therapeutic treatment for EHNV infection of trout.

Harvest and postharvest handling

Trout grown in ponds and raceways are usually harvested by some combination of seine or crowder nets and dip nets. Fish pumps or mechanical lifts are also used, sometimes in combination with electronic counters and/or mechanical graders. Ideally, the select grade harvested fish are then chilled in an ice slurry before immediate processing. Although such quality assurance procedures are not yet standard practice for all farmers, there is increasing pressure to adopt them because of a more discerning marketplace and more stringent regulations with respect to community health.

Freshly harvested farmed rainbow trout

In general, the normal fresh-food industry and associated government health standards apply. For any value-added processing, such as smoking, specific training is required. For economic reasons, not all trout farms undertake on-site processing and/or value-adding, preferring instead to be contract growers; processing and value-adding being undertaken elsewhere by another operator.

Economics of production

Given that land-based trout farming is a relatively mature industry sector with reasonably orderly markets, production costs are generally considered to be low in comparison with other aquaculture industry sectors/ products in Australia. With such narrow profit margins, the industry places a premium on efficiency of production. Consequently, economies of scale dictate larger-volume production for individual businesses to achieve long-term economic viability. Large-volume production is also essential because existing domestic demand is being met by existing local production.

There are opportunities for the export of land-based farmed trout products but market prices would be marginally less than on the Australian domestic market, because of competition from other countries. International competition for farmed salmonid products is relatively severe at the present time because of increased global production and an associated decline in world market prices. Only about 5% of Victoria's total annual production is exported from two AQIS-approved export processing facilities.

Major operating costs include fertilised eggs and/or fingerlings (if purchased), feed, labour, water, energy (particularly if pumping water), insurances, rates, miscellaneous licences, processing, packaging, freight, marketing (advertising), depreciation on capital and interest on borrowing. Major capital costs include ponds, raceways and tanks, broodfish (for hatchery), pumps, production equipment (e.g. graders, fish pumps, scales, counters, and nets), bird netting, security fencing, processing plant and equipment, vehicles, and cold storage facilities. Capital and operating costs typically vary with the species, product type, geographic location and scale of operation.

For a medium to large-sized farm (100–300 t/year production capacity), production costs range from $4–5/kg for conventional, fresh/frozen, gilled and gutted whole fish, up to $15/kg for value-added products, such as smoked fillets.

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Yabbies

Craig Lawrence

Introduction

Yabbies (*Cherax albidus and Cherax destructor*) are indigenous to central and eastern Australia and have received considerable aquacultural interest. Although some yabbies are produced from ponds on purpose-built farms, the vast majority of commercial yabbie production in Australia comes from trapping in farmers' dams what are essentially wild yabbies. This use of existing farm dams originally built to water stock has enabled rapid expansion of the industry because of the low entry cost. The yabbie industry currently harvests around 4000 farm dams in Western Australia. The rapid growth experienced by the industry is expected to continue, with processors reporting an increase this year of up to 400% in the number of farmers harvesting yabbies.

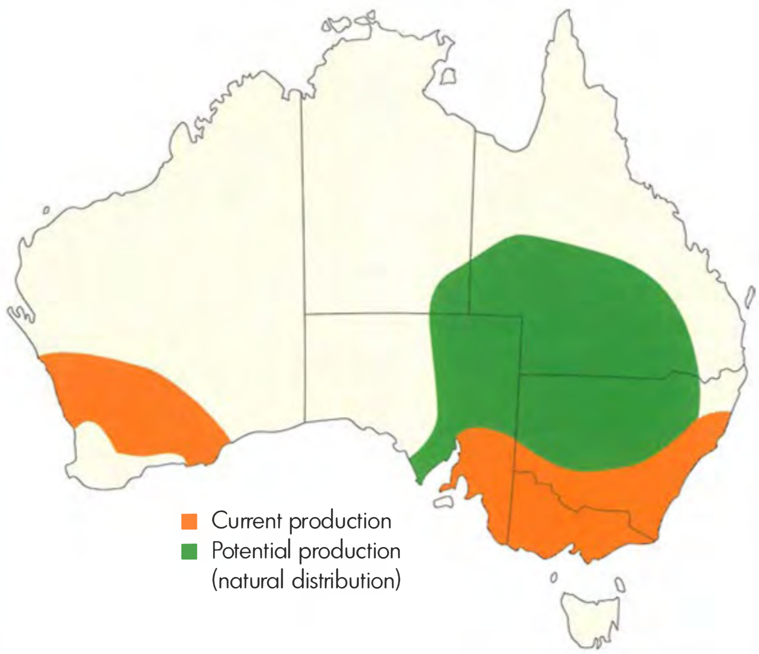
Australian yabbies are in demand internationally due to their high quality, larger size than crayfish produced by overseas competitors, acceptance by European markets as a replacement for diminishing stocks of their own native crayfish, freedom from major diseases and ability to be landed live in the major international markets.

Markets and marketing issues

Yabbies are sold both domestically and in export markets in Europe and Asia. Approximately 70% of Western Australian yabbie production is exported.

One of the key strengths of yabbies is that they can be exported alive, out of water and arrive in prime condition not only in capital cities in Australia, but also on high value markets in Europe and Asia. International demand for freshwater crayfish is expected to continue to increase. This is the result of a number of factors, but particularly continuing demand from traditional European consumers of freshwater crayfish combined with decreased domestic supplies there because of crayfish plague, a disease which has swept through Europe killing many of their native populations of freshwater crayfish. Australia is the only continent with freshwater crayfish that have not been infected by the disease, and our strict quarantine regulations should ensure that this valued status is maintained.

Yabbies are graded according to weight and condition. Weight grades and prices vary around Australia. Average weight grades are presented in Table 1. Higher prices are paid for yabbies which



are purged, graded and/or packed by the farmer. Most processors pay higher prices for larger yabbies; this reflects the demand for larger crayfish and the greater difficulty in producing large yabbies. As the price of wild caught yabbies may drop as low as $2.00/kg, it is essential that all farmed yabbies are clean, purged and graded in order to maintain their market share and higher prices.

Table 1. Average Australian prices paid for different size classes of yabbies.

Size grade	Farm-gate price ($/kg)
below 30 g	No commercial value
30–40 g	5.00
40–50 g	7.00
50–60 g	8.00
60–70 g	9.00
70–80 g	10.00

Production requirements

The production of yabbies from farm dams has experienced rapid growth over the past 10 years, from a total of 1.5 t in 1987 to almost 300 t in 1994 (Fig. 1). Nevertheless, the production of yabbies from farm dams can be affected by drought, as was the experience in 1995–96 when low rainfall resulted in many farm dams drying up with a consequent reduction in yabbie harvests.

The production of yabbies from 'semi-intensive' ponds has shown slower, but steady, growth over the past 10 years, with production increasing to around 50 t in 1995–96 (Fig. 1).

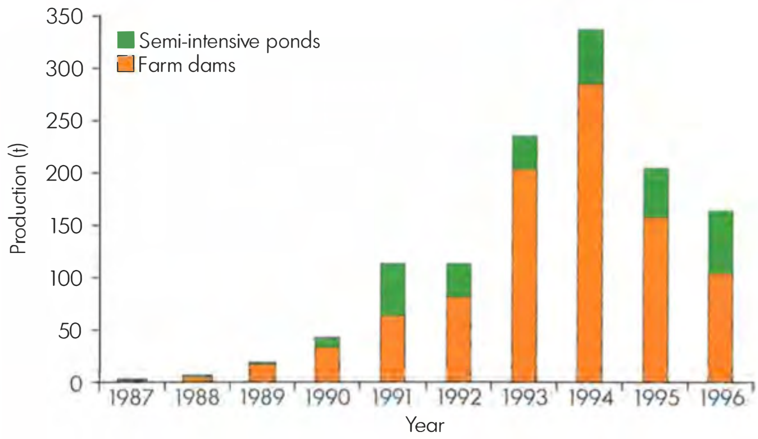


Fig. 1. Annual yabbie production from semi-intensive ponds and farm dams in Australia.

About the author

Craig Lawrence has a Masters degree in Aquaculture from the University of Stirling (U.K.) and extensive international aquaculture experience. For the past 6 years he has been employed as a Research Scientist (Aquaculture) with the Fisheries Department of Western Australia. See *Key contacts* for address.

The regions in which yabbies are currently farmed are shown on the accompanying map, but the distribution of yabbies is much wider than the farming areas—they occur naturally throughout most of central and eastern Australia.

In farm dams and ponds, yabbies spawn annually from early spring to mid summer. Yabbies spawn so readily there is generally no need to purchase juveniles, with most farms producing more stock than they require. In fact, a major problem in yabbie farming is the over-population of yabbie dams and ponds, which results in stunted growth and smaller individual animals.

Yabbies thrive in the warmer, drier, inland regions of Australia. Optimal water temperatures for growth are in the range 24–28°C. Growth ceases at water temperatures over 34°C and below 15°C during winter.

Growth of yabbies ceases at salinities above 8 parts per thousand (ppt), which is about one quarter seawater. At salinity levels above about half seawater mortalities occur.

Yabbies can tolerate dissolved oxygen levels lower than one part per million (ppm) for short periods. However, feeding activity, and hence good growth, are dependent upon healthy, well-oxygenated water conditions.

For many farmers, the major limitation to increased yabbie production is the amount of water available. Sites for yabbie farming must have soils containing sufficient clay to minimise seepage and adequate rainfall or water supplies to not only fill dams or ponds but also replace water lost due to evaporation and seepage.

Varieties

The name yabbie is derived from an Aboriginal word for freshwater crayfish. Although the taxonomy of yabbies has been reviewed a number of times, in general, these studies have focused upon whether different varieties of yabbies belong to the same or separate species. From an aquaculture perspective, it is perhaps more important to recognise that there are a number of 'varieties' of yabbies, some of which are more suitable for farming than others.

Cherax albidus is the species to which the yabbies found in Western Australia belong. These yabbies, originally from Merwyn Swamp in Victoria, were introduced into farm dams around Narembeen in Western Australia around 1932. Most of the yabbies found in central and eastern Australia are *Cherax destructor*, a closely related species.

Although there are a number of 'varieties' of freshwater crayfish which are collectively referred to as yabbies (i.e. *Cherax albidus*, *C. destructor*, *C. cuspidatus*, *C. rotundus*) most yabbies produced in Western Australia are *Cherax albidus* and in central and Eastern Australia either *Cherax albidus* or *Cherax destructo*.

Seed stock is available throughout the range in which yabbies occur naturally. As yabbies reproduce readily in farm dams or ponds only an initial stocking is usually required, after which supplies of juveniles can be produced easily in the pond or dam.

Fish husbandry

Farmers producing yabbies using extensive farm dam production have reported yields of 400–690 kg/ha of water area per year. However, as a result of uncontrolled breeding, a significant portion of this production is below market size. Farm dams cannot be readily drained for (i) efficient harvesting during winter; (ii) stock control against over-breeding; or (iii) cleaning out of the bottom mud when sediments become over-enriched. Juveniles may be stocked in farm dams at 1–2 individuals per square metre.

Harvesting yabbies from dams by seine netting damages the animals and can result in bacterial infection from mud stirred up from the bottom. Consequently, yabbies are harvested from dams using baited traps.

Key statistics

According to figures published by ABARE (1997) yabbies valued at over $2.1 million were produced in Australia in 1996. The breakdown of production is shown in Table 2. A significant percentage of production was exported live to markets in Europe and Asia.

Table 2. Value and origin of Australian production of yabbies in 1995–96.

State	95–96 ($'000)	%
WA	1230	58
NSW	409	19
VIC	325	15
SA	175	8
Total	2139	100

The yabbie occurs naturally throughout central and eastern Australia, and was introduced into Western Australia.

Regular feeding helps yabbies to grow faster.

Because yabbies are less inclined to feed in winter, capture becomes more difficult using baited traps at low water temperatures. Consequently, the harvesting of yabbies from dams by trapping results in seasonal fluctuations in supply similar to that experienced in wild fisheries.

The use of purpose-built ponds for more intensive crayfish farming has a number of advantages over widely spread and isolated farm dams. Semi-intensive crayfish production in such ponds gives average yields about 5 times those of farm dams. These ponds may be rapidly and completely drained via a gravity drain outlet for complete harvesting, pond repair, bottom cleaning, liming and disease control by allowing the ponds to dry out. Ponds used in yabbie farming are usually 0.5– 2 m deep at the outlet and about 0.1 ha in water area. Each pond has a piped water supply and a water level standpipe in the pond's bottom outlet. The pond outlet has a screened concrete sump to collect yabbies.

A set of ponds is fenced and may also have bird netting to exclude predators. To prevent temperature and oxygen stratification, good ponds have a very small freeboard, less than 0.5 m, between the top bank and the water level. Also, the long axis of the pond should be aligned with the prevailing wind to enhance circulation and oxygenation. The high rate of daily feeding needed to get the high production levels in semi-intensive yabbie culture, requires the installation of a mechanical, mains-powered aerator. Juveniles may be stocked in these semi-intensive ponds at a density of 5 individuals per square metre.

Due to the leaching of nutrients, the development of nutritionally complete diets for freshwater crayfish is complex. Consequently, while supplementary feeding is essential for higher than natural crayfish production, crayfish make up for the deficiencies of essential micro-nutrients in the artificial feed by also eating natural food in the dam or pond. Nutrients which leach from the artificial feed, fertilise the water body and encourage the production of natural foods.

Currently, the most common feed used for yabbies in farm dams in WA is lupins, at the rate of 2.5 g/m^2 of water area each week. However, improved growth rates for yabbies in farm dams have been achieved using crayfish pellets at the rate of 2.5–5 g/m^2/ week. In semi-intensive pond production, yabbies are usually fed crayfish pellets at between 2.5–10 g/m^2 each week. Use of aerators allows the higher feeding rates used in ponds.

Key messages

- Large international markets exist for our live disease-free yabbies
- Yabbie farming does not require complicated hatcheries or equipment
- Yabbies are a native species that are adapted to Australia's harsh climate.
- Yabbies can be exported live to international markets

Growth of yabbies is temperature and density dependent. Although individual growth of yabbies, as in other crayfish, is always highly variable, the minimum market size of 30 g can be achieved in less than 6 months.

Pest and disease control

Surface fouling on yabbies by ectocommensals, such as the protozoan *Epistylis* and the platyhelminth (or flatworm) *Temnocephala*, although rarely harmful to the animals unless in extremely high densities, lowers the market appearance of affected individuals. These so-called epibionts are symptomatic of waters which are over-enriched with nutrients. This usually occurs due to nutrient enriched run-off entering farm dams or overfeeding in semi-intensive ponds.

The microsporidian *Thelohania* infects yabbie and other crayfish populations in eastern Australia but is not present in the West; consequently, to protect Western Australian stocks this State bans the importation of live crayfish.

All Australian crayfish, including yabbies, are susceptible to the crayfish plague of the northern hemisphere, a fungal disease *Aphanomyces astaci*, found on American crayfish and which has devastated European crayfish populations. Consequently, in order to protect our native populations and aquaculture industry, the importation to Australia of any species of live crayfish which may carry this disease is not permitted

Harvesting and postharvest handling

Yabbies are harvested from dams using baited traps or collected from ponds after draining.

Upon harvesting from farm dams, yabbies must be gill washed immediately to prevent mortality due to bacterial infections arising from bottom sediments trapped in the gill chamber. They should then be held in a cool, moist atmosphere.

Because yabbies are exported live, very little processing is required by commercial yabbie farms to supply markets direct. In Western Australia and South Australia a highly successful system has developed where farmers or professional yabbie harvesters trap yabbies from farm dams. The yabbies are then gill washed and placed in cool boxes which are delivered to a centrally located processor. The processor buys the freshly harvested yabbies from the farmer or harvester and places them into purging tanks. The yabbies remain in these tanks, where they are not fed, for a minimum of 48 hours to purge their hind guts and greatly improve the flavour and travelling condition.

Yabbies are harvested from farm dams using baited traps.

The yabbies are graded according to condition and the weight grades shown in Table 1. The processor combines all of these small harvests from a large number of dams or ponds to provide enough yabbies to supply large international orders. To ensure that yabbies arrive at their destination in top condition, before export they are cooled, then packed between layers of foam in polystyrene boxes with ice bottles.

Economics of production and processing

The establishment costs for farm dam production of yabbies are very low. The only essential equipment is traps to catch the yabbies and containers for gill flushing and transportation. Alternatively, farmers may elect to have commercial harvesters trap their yabbies and receive a percentage of the crop value.

Commercial semi-intensive pond production is much more expensive with establishment and operating costs similar to those of a marron farm (see chapter on marron).

A case study of the economics of harvesting yabbies from a farmer's dams was undertaken in 1996 by an extension officer employed by the Fisheries Department of WA. In 1996, this farmer produced 3000 kg of marketable yabbies, which grossed $19,000. The study showed that the farmer, who had 46 dams, incurred the following costs;

Initial establishment costs

Item	Cost
Yabbie mover (inc. trays)	2200
75 yabbie traps	2475
Buckets to gill wash yabbies	50
Grading tray	47
Total	4772

Annual operating costs

Item	Annual cost
Feed	2053
Fuel, vehicle cost	2900
Bait	243
Ice	300
Total	**5496**

Income

Yabbies	Income
3000 kg	19 000
Total	**19 000**

Thus, after subtracting working costs from the $19,000 gross income for 1996 the farmer received $13,504 for the year.

The farmer spent 360 hours, or approximately 7 hours per week on harvesting and feeding the yabbie dams, providing a return of $37.51/hour for labour.

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Contact names and addresses for local freshwater crayfish industry associations are published regularly in *Freshwater Farmer Magazine.*

Freshwater Farmer Magazine
Les Gray
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Torrens Park, SA 5062

Key references

Freshwater Farmer Magazine – published quarterly

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Asian Vegetables

Burdock

Vong Q. Nguyen

Introduction

Burdock (*Arctium lappa* L.) which belongs to the chrysanthemum family (Compositae), is a native of Asia. It has become naturalised in many parts of the world, growing wild throughout Europe and North America where it is used as folk medicine. The Japanese developed it as an edible vegetable when it was introduced into Japan probably a thousand years ago. Today, large areas of burdock are grown only in Japan. Taiwan, China and other South East Asian countries produce some burdock mainly for export to Japan but the import of burdock into Japan at present is small.

Burdock is a biennial plant that is grown and harvested as an annual. Seeds are not produced until the second year. The plant carries its leaves on long stems (approximately 60 cm), originating from the crown. Leaves are large, almost heart-shaped, have a rough texture and are covered with short white hairs, dark green on the top and a paler green underneath with pinkish veins.

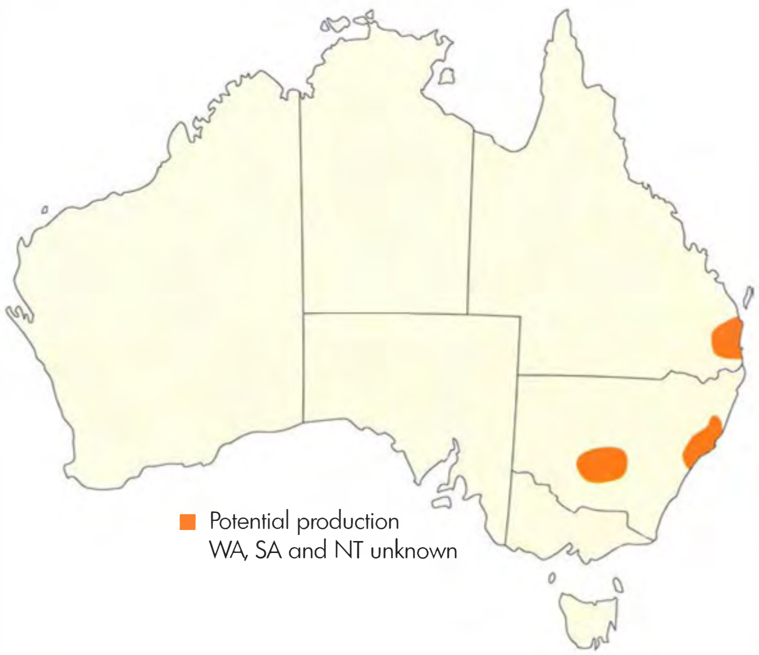
The long, tapering tap-root can reach lengths of up to 120 cm. However, roots grown for fresh markets need to be 60–90 cm long and less than 3.5 cm in diameter at the crown. Roots usually have a brown skin with white flesh that oxidises (discolours) quickly when exposed to air.

Burdock is tasty and high in fibre, potassium, calcium, iron, silicon, sulphur, volatile oil and resin as well as containing several antibiotics and it has recognised medicinal properties.

While the consumption of burdock in Japan is stable, the production area is falling (Table 1). This offers an opportunity for Australia to supply the market, particularly during the period from April to June when fresh burdock is in short supply throughout Japan.

Markets and marketing issues

Japan produces approximately 200,000 t of burdock annually (Table 1), valued at about ¥60 billion at wholesale markets, equivalent to approximately A$800 million. Tokyo's wholesale markets represent some 8% of Japanese sales. Data from 1992 to 1996 show that the average annual throughput for burdock is 15,699 t with an average annual price of ¥299/kg.



The largest volumes of Tokyo markets throughput are from September to December with the lowest wholesale prices, while the higher wholesale prices are from January to June, particularly April, May and June (Table 2).

International trade in burdock focuses on Japan, though at present the import of burdock into Japan is negligible. In 1994, Japan imported approximately 421 t of fresh burdock which represented only 0.2% of the domestic throughput. China supplied the greatest amount of 300 t at an averaged landed price of ¥130/kg during the period of January to April. The Philippines also supplied Japanese markets in April and May with 120 t at an average price of ¥153/kg.

Burdock has also been imported into Japan from Taiwan and South Korea. However, information about exports from these countries is not available.

Table 1. Production of burdock in Japan, 1989–94[a]

	1989	1991	1993	1995
Planting area (ha)	15,200	14,100	13,700	13,400
Production (t)	219,000	187,300	191,900	190,000
Wholesale (¥/kg)[b]	291	424	304	263
Retail (¥/kg)	687	820	775	702

[a] Note: Norin suisan toke 1996 (Ministry of Agriculture, Forestry and Fisheries, 1996. Statistical information) (In Japanese).
[b] Wholesale prices at Tokyo wholesale markets.

Table 2. Wholesale market throughput and price of burdock at Tokyo wholesale market 1992–1996[a]

Month	1993		1995		1996	
	V[b]	P[c]	V	P	V	P
January	1,003	226	937	222	930	298
February	1,234	221	1,147	236	1,165	304
March	1,390	205	1,199	237	1,164	328
April	1,299	241	1,094	272	1,101	351
May	1,126	262	1,176	307	1,039	380
June	1,028	276	1,103	306	1,013	341
July	1,084	312	959	292	1,062	298
August	851	416	854	266	963	254
September	1,165	466	1,389	275	1,422	233
October	1,592	383	1,586	244	1,608	197
November	1,517	319	1,549	251	1,697	178
December	2,426	316	2,278	257	2,380	182
Average	15,714	304	15,272	263	15,543	263

[a] Source: 1996 Tokyo wholesale markets, Annual Report of Fresh Fruit and Vegetables, Vegetables Section, Tokyo Fresh Fruit and Vegetable Information Centre (In Japanese).
[b] V = Volume, tonne
[c] P = Price, ¥/kg; A$ = ¥75.2 in 1994

About the author

Dr Vong Nguyen is a Special Research Horticulturist with NSW Agriculture at the Gosford Horticultural Research and Advisory Station (see *Key contacts* for address). Born in Vietnam, he studied in Japan and received his PhD from the University of Tokyo, Japan in 1977. He is currently involved in research into the development of Asian vegetables for domestic consumption and export to Asian markets.

Production requirements

Burdock is a temperate crop that tolerates a wide range of temperatures. It prefers warm, humid climates and grows best at temperatures of 20–30°C. However, it will tolerate much higher temperatures. Leaves die back when frosted, but roots will survive in soil when air temperatures are well below 0°C and roots will re-shoot the following spring.

For quality roots, sandy soil or sandy loam are best. Soil must be deep, with no change in profile to at least 60 cm, and must have good drainage. Soils need to be worked to the full depth of the final root size to prevent forking. Burdock does not like acid soils, and the optimum pH range should be between 6.0 to 7.5.

Burdock for sale as a vegetable is harvested from first-year plants, normally at four or five months' growth if planted in spring, or seven to eight months' growth if planted in autumn.

Varieties (cultivars)

In Japan, burdock is classified into several groups such as Takinogawa, Oura, Hagi and Echizen Shiroguki.

Takinogawa, which is the most common group, has slender, long roots and red petioles. Popular cultivars for this group are Takinogawa, Watanabe wase, Yamada wase, Tohoku riso, Shinden, Nakanomiya and Tokiwa.

Oura, *Hagi* and *Echizen shiroguki* have thicker and shorter roots. Cultivars of the Oura group include Oura and Horikawa; the Hagi group include Hagi and Hyakunichishaku and the Echizen Shiroguki group including Shiroguki wase.

There is a very small demand for the burdock leaf. The leaves are taken from small plants two to three months old and grown in shade and at a very high density planting.

Agronomy

Burdock can be sown in spring and autumn. Spring burdock can be sown as soon as soil temperatures are above 10°C. A better establishment will be achieved if planting is delayed until the soil has reached 15°C. Seed germination is very slow, taking 10–14 days for emergence, and can be uneven. In fact, some seeds may lie dormant in the soil and germinate the following autumn. Using primed seed breaks this dormancy and increases both the rate of germination and overall percentage of germinated seed (Fig. 1).

Growing burdock (gobo) in NSW for Australian fresh markets and export to Japan

Burdock in the Ota Wholesale Market, Tokyo, Japan

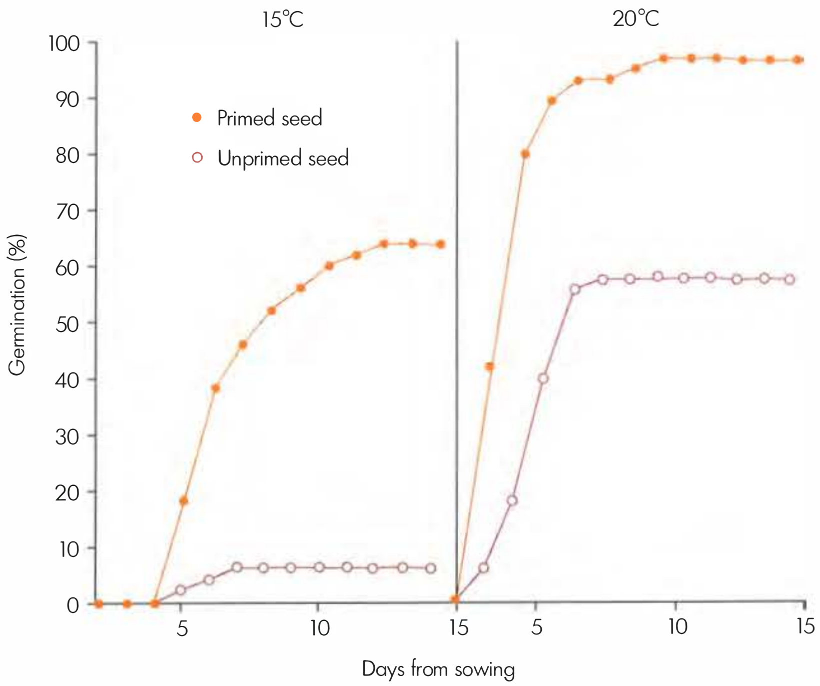
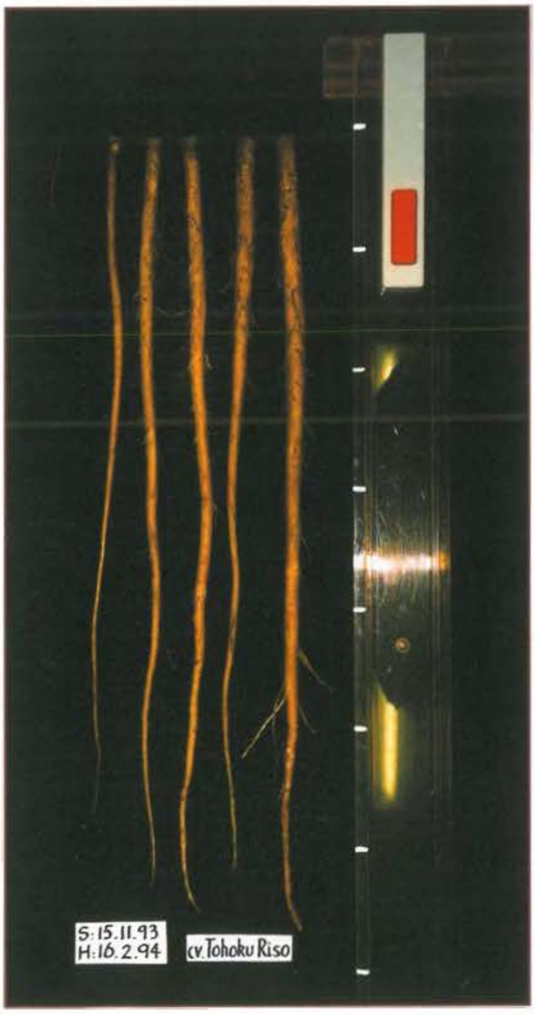


Figure 1. Priming burdock seed increased both the rate of germination and the final percentage of germinated seed at both 15°C and 20°C.



Burdock, cv. Tohoku Riso, performed very well under Australian cultural and climatic conditions. Burdock can be produced throughout the year but from January to June is the best time for shipment to Japan.

Autumn burdock must be sown late so that plants are still very small when the first frost occurs. Leaves will die back and the plant stops growing until temperatures become warmer in spring. There is a risk of plants bolting (going to seed) in spring if roots are larger than 5 mm diameter before winter. Autumn sowing produces an earlier crop during the following spring/summer.

Before sowing, the soil must be cultivated very deeply — up to 90 cm if possible. Soil must be left in a loose, friable state for roots to penetrate otherwise they will fork and the yield of 'A' grade roots will drop dramatically. Up to 80% of roots that fork do so in the top 15 cm due to either a change in soil structure where soil has been shallow cultivated, or if fertiliser with a high N content is banded below the seed line (Fig. 2).

A fertiliser with low nitrogen and high phosphate to encourage root growth can be worked into the soil before sowing during deep cultivation. Apply approximately 120 kg/ha P in sandy soils. This rate can be reduced in more fertile, sandy loam or alluvial soils.

Two side dressings of nitrogen and potassium fertiliser should be applied, the first at the two-three leaf stage (approximately 60 kg/ha of elemental N and K) and the second approximately three months after sowing (100 kg/ha of elemental N and K).

Burdock is direct-seeded with 10 cm between plants and approximately 50 cm between rows. Seeds should be sown at about 1–2 cm deep and kept wet until after seedlings become established. Once plants are established, water can be cut back to force roots to seek moisture deeper in the soil profile. It is important not to over-irrigate and saturate the soil profile as excessive moisture can lead to root rot diseases.

Pest and disease control

As burdock is a new crop to Australia, there are no registered chemicals available for weed, pest and disease control. However, burdock is a hardy plant and has few pests or diseases and weeds can be controlled with cultivation and hand chipping.

The slow establishment rate of burdock gives weeds a head start on the crop so it is important to ensure that the site is prepared well in advance of the sowing date. The site should be pre-irrigated and any emerging weeds sprayed off with a knockdown herbicide just before or immediately after sowing. Weeds that establish after the crop has emerged have to be cultivated out or hand chipped. The crop will form a complete canopy approximately eight weeks after germination, which restricts further weed establishment.

A burdock crop grown chemical-free may attract a premium price in Japan where consumers are very health conscious and have shown a willingness to pay extra for 'organically clean', healthy, quality foods.

Nematodes (burrowing nematodes) are a major pest and soils should be assessed for nematode populations before sowing. A nematode-repelling crop, such as oats or rape, may be sown as a cover crop during winter and incorporated into the soil before sowing burdock.

In some years, red-legged earth mite can cause damage to young seedlings early in the season. If earth mite are likely to be a problem, planting should be delayed until their activity diminishes.

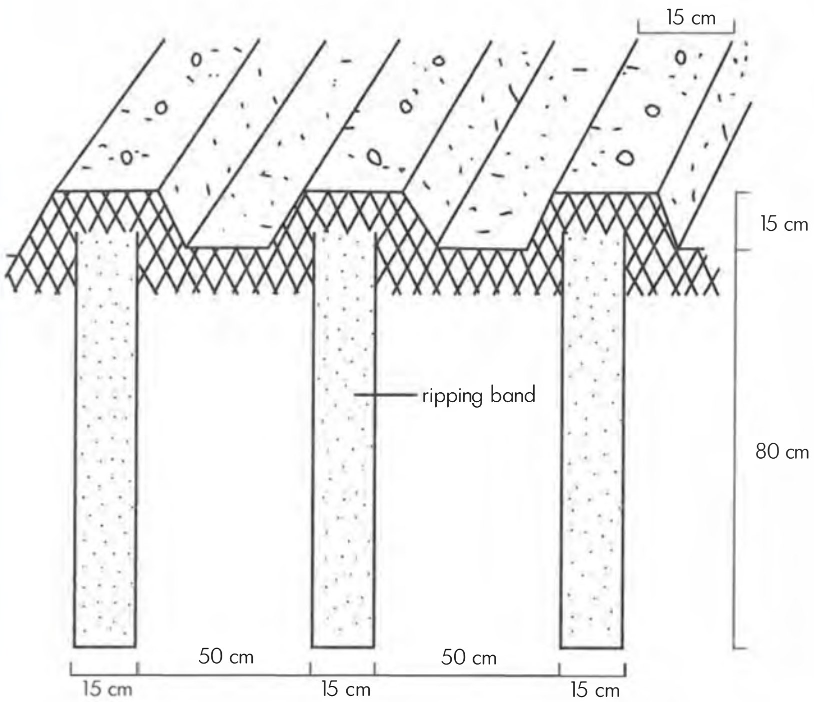


Figure 2. Preparation for burdock sowing: deep ripping (60–80 cm) to encourage roots to grow longer.

Burdock sold in Tokyo supermarket, Japan

Powdery mildew may become a problem in mid- to late summer if wet, humid conditions prevail. Symptoms are similar to powdery mildew on cucurbits though the causal agent is different. In most cases the crop will tolerate a mildew infection and it is only in extreme circumstances that crop losses will occur. Wettable sulphur (a natural compound) can be used to control powdery mildew if it is deemed necessary.

Black root is a fungal disease caused by *Aphanamyces raphani*, which may also cause crop losses. Warm, hot weather and water-logged soil favour its development. The disease is controlled by correct irrigation scheduling, good drainage and crop rotation.

Harvesting and packaging

Spring-sown burdock will be ready for harvesting about 4–5 months after sowing. To obtain the best commercial return, the crop should be harvested when most of the roots are 20–35 mm diameter and at least 70 cm long. If harvest is delayed to increase tonnage, quality will decline. Roots will be over-mature and become woody and pithy and the market will not accept them.

To harvest burdock, shoots are first removed by slashing or mulching the tops, leaving approximately 10 cm of stalk. Roots are then loosened with a vibrating ripper then pulled out by hand. It may be possible to pick up the roots with a modified carrot harvester once they have been loosened. After the roots are lifted from the soil, they must not be left exposed to the hot sun as this causes them to wilt and the skin quickly oxidises and becomes discoloured. Harvesting should be carried out early in the morning and the burdock taken to a shady area or packing shed as quickly as possible.

The fresh market in Japan demands long, straight roots without any forks or side shoots. Roots need to be at least 60 cm long (preferably 70 cm) and between 16–35 mm diameter (see Table 3 for grade sizes). Shorter or forked roots may be sent for processing at reduced price.

Roots are then washed and side shoots and root hairs are removed. After washing and trimming, roots are graded and packed into plastic-lined 10 kg cartons. Table 4 also lists the fresh market grades that are used in Japan.

Quarantine requirements

A declaration must be provided to the Australian Quarantine Inspection Service (AQIS) that the burdock crop has been inspected by an authorised person and is free of burrowing nematode (*Radopholus similis*). The crop must have been grown on a farm that has been inspected by soil sampling during the growing season and found to be free from *Radopholus similis*. *Radopholus similis* does not occur in the Riverina of New South Wales, but is present along the north-east coast of Australia, especially in banana-producing areas. A further requirement is that all soil must be removed from the roots.

Future outlook

It is evident that in Japan burdock brings higher prices in the first half of the year, particularly April, May and June. However, data of import into Japan (Table 3) have shown that the imported prices in April and May with ¥140/kg and ¥160/kg respectively were not as good as the average wholesale prices at Tokyo markets with ¥382/kg and ¥407/kg (Table 2) for April and May respectively.

Table 3. Burdock size grading for Japanese markets.

Sub-grade	Size	Root diameter (mm)	Root length (cm)
A	3L	≥36	>60
	2L	31–35	>60
	L	26–30	>60
	M	21–25	>60
	2M	16–20	>60
	S	11–15	>55
	2S	≤10	>35
B	BL	>35	45–60
	BM	25–35	45–60
	BS	>15	45–60
	Process	>20	>40

Table 4. Gross margins for burdock production in the Riverina of New South Wales.

Unit: 1 hectare Location: Riverina, New South Wales				Standard budget $/ha.
Income: Yield 10.00 t @ $2.00/kg FOB				20,000.00
			A. Total Income:	**$ 20,000.00**
VARIABLE COSTS:				
Land preparation:				
Tractor operation	Tractor time		Tractor cost	$
Rotary hoe (×2)	1.00		12.61	25.00
Rip	2.00		75.00	150.00
Boomspray	0.50		12.61	6.30
Broadcast	0.30		12.61	3.78
Fertiliser			402.00/t	201.00
Nematicide	24 L/h	@	39.00/L	936.00
				$ 1,322.30
Sowing:				
Seed	2.5 kg/ha	@	100/kg	250.00
Sow	1.5 hr/ha		12.61	18.92
				$ 268.92
Growing:				
Boomspray (×2)	0.20		12.61	10.09
Side dress urea (×2)	0.5		12.61	12.61
Urea	350 kg	@	330/t	116.55
Weed control:				
Cultivation (×2)	1.5		12.61	37.83
Fusilade® (×2)	80/L	@	0.751/ha.	120.00
Chipping	1	@	400/ha	400.00
Chipping	1	@	250/ha	250.00
Irrigation	7.5 mL/ha	@	35/mL	262.50
Pumping	7.5 mL	@	17/mL	127.50
				$ 1,337.08
Harvesting:				
Slashing	1		30.00	30.00
Ripper	4		75.00	300.00
Hand harvesting	1,500/ha		12.61	1,500.00
Wash, grade and pack			0.50/1,000	5,000.00
Cartons	1,000	@	1.50	1,500.00
				$ 8,330.00
Distribution:				
Freight MIA-Sydney	165/t			1,650.00
Handling charges				2,150.00
			B. Total variable costs	**$ 13,408.30**
			Gross margin per ha (A–B)	**$ 6,591.70**

It is understood that the low imported prices are due to low production costs in such supplier countries such as the Philippines. Low Japanese yen currency (A$ = ¥88 at June, 1997) would also be an important factor for the import price into Japan. The break-even price for New South Wales burdock is A$1.34/kg (Table 4).

It should be noted that the production costs vary between seasons, growing locations, time of consignment and the business resources. Break-even costs do not include profit or return on capital invested.

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Chinese broccoli

Stephen Moore
Wendy Morgan

Introduction

Chinese broccoli (*Brassica oleracea* L. var. *alboglabra* Bailey) belongs to the Crucifer family, which includes vegetables such as cabbage, broccoli, cauliflower, radish and turnips. It has other common names such as kai lan and gai lum. Chinese broccoli is also closely related to the European broccoli and the Portuguese 'Couve Tronchuda' cabbage. It was probably introduced into China from the Mediterranean during ancient times.

The whole plant can be eaten, but the older leaves and stems are generally stringy and discarded. Young leaves and stalks (15–20 cm high) with compact florets are selected, because they are sweeter and more tender.

Chinese broccoli is a perennial plant that is often grown commercially as an annual. The leaves of Chinese broccoli are oval, glabrous and bluish/green. The average spread of Chinese broccoli is between 25 and 37 cm and depending on the variety, it grows to about 45 cm in height.

Markets and marketing issues

In Australia, Chinese broccoli is available at most major wholesale markets and Asian grocery stores throughout the year. The wholesale price ranges between $0.50 and $1.00/bunch. The Melbourne Markets average wholesale price is between $0.90 and $1.50/bunch. The average retail price in and around Melbourne is between $1.00 to $1.60/bunch.

Chinese broccoli is widely sold and is one of the main Asian vegetables grown in New South Wales and Victoria.

Production requirements

Chinese broccoli is a cool-season crop and has some frost tolerance, preferring uniform conditions that are not too dry, wet or shady. Young plants should be protected from the wind.

Chinese broccoli is shallow-rooted like most other brassica crops and requires frequent watering for optimum growth. Water should be applied frequently but lightly. Light watering reduces the chance of leaching nutrients out of the soil. Frequent watering encourages healthy plant growth.

The amount of water needed is influenced by soil type, with sandy soils draining very quickly and requiring more frequent watering than other soils. The ideal soil type for vegetable production is fertile and has good drainage along with a high content of organic matter. The soil pH should be between 6.0–7.0 and should not fall below 5.0.

Varieties

Chinese broccoli varieties are differentiated by their flowering period, so they are conveniently classified into early, mid and late season. Different varieties may have white or yellow flowers or a wrinkled leaf; the major commercially grown varieties have white flowers. Hybrids (e.g. F1 Green Lance) are generally more vigorous than the common white-flowered varieties. A much smaller yellow-flowered variety (Chinese Yellow Broccoli) is recommended for summer production.

Chinese broccoli can be grown successfully all year provided different varieties are used in accordance with the season or climate. Matching the varieties with different seasons or climates can be difficult: there is little information on varieties, seasons can change yearly and climates can be markedly different from place to place. For example, summer-grown Chinese broccoli was bitter in taste and disliked by consumers. The poor quality came from using the wrong varieties for that time of year.

Chinese broccoli

Agronomy

The rates of fertiliser for optimum crop development can differ markedly between soil types. Soil testing is the best way to determine what is needed. Two suggested fertiliser mixes for Western Australian soils, are as follows :

1. Sandy Soils. A base dressing of 50 m^3/ha poultry manure, 1.25 t/ha superphosphate and trace elements. A side dressing of 150 kg/ha Agran 34-0 and 150 kg/ha muriate of potash should be applied about one, three and five weeks after emergence

2. Medium and Heavy Soils (Poor fertiliser history). Base dressing of superphosphate (2 t/ha), muriate of potash (600 kg/ha) and trace elements. A side dressing of Agran 34-0 (200 kg/ha) should be applied about one week after emergence and Agran 34-0 (100 kg/ha) about three and five weeks after emergence

In trials of three forms of base fertilisers (each supplying 67 kg N/ha) on Chinese broccoli, the best results were obtained from:

(1) commercial organic-inorganic fertiliser mix (3.5% N, 3.5% P and 2.7% K) at a rate of 1900 kg/ha,

(2) well-rotted cow-manure (1.0%N) at a rate of 1000 kg/ha, plus inorganic fertiliser (15% N, 6.5% P and 12.5% K) at a rate of 380 kg/ha, and

(3) inorganic fertiliser (15% N, 6.5% P and 12.5% K) at a rate of 447 kg/ha.

The differences between fertilisers were associated with the organic matter content which produced a better soil structure. Fertilisers with too much organic matter (e.g. 45%) reduced the availability of nutrients and performed poorly.

Chinese broccoli can be sown directly or transplanted in rows about 3 cm apart and spaced/ thinned to about 10 cm. Seed can take 4–10 days to emerge from a sowing depth of 0.6 cm during autumn and 3–6 days in summer. Transplants are generally planted 3–4 weeks after sowing the seed. The growing time from seeding to harvest averages 50 days during February to December.

Chinese broccoli can be grown close together to give a more desirable product, which is not large and tough stemmed. The closer spacings slow down the maturation process and produce less fibrous plant tissue, which is indicated by a high leaf-area index. If the inter-plant spacing is decreased, there is a reduction in the crude fibre content and an increase of marketable and total yields.

Plant spacings reduced from 30 cm to 20 cm and 10 cm, result in a progressive increase in fresh-weight yield/ha. However, a lower mineral content is found in the plants at the closest spacing of 10 cm. The lower mineral content results from increased competition for nutrients. Transplants may reduce the competition for nutrients between plants.

In Malaysia, transplants when harvested at six weeks after transplanting (eight weeks after sowing), yield about 53% more marketable fresh-weight and with a higher mineral content than the direct-seeded plants of the same age (8 weeks). Additional fertiliser should also reduce the competition for nutrients between plants.

Pest and disease control

See Chinese chard.

Harvest, handling and postharvest treatments

Chinese broccoli matures quickly without much attention. Its shoots can be ready to harvest in 10 weeks from sowing during autumn and 8–9 weeks from sowing during summer. On average it takes 65 days from sowing to maturity. Chinese broccoli should be harvested frequently, especially during the hot weather, to prevent premature bolting and to prevent the shoots from becoming tough.

The time of harvest is critical. The plants are generally harvested with a knife well before any buds begin to open and no later, because then the flavour is at its best. The flowers may open only slightly without spoiling the flavour. The main flower stalk should be cut relatively short to allow sufficient regrowth for further harvests. A liquid feed after each cut may be beneficial and other shoots grown beyond the first three cuts are generally not worth harvesting.

The time of harvest of most Asian vegetables is critical for high quality produce. Harvesting in the cool of the morning is preferred because it reduces moisture stress. Once picked, the plants are bunched into groups of five to seven and tied. The main stem should be long (10–15 cm) and thick in diameter (1.5–2.0 cm at the base). Chinese broccoli should be presented free of roots and with or without flowers. The plants should be fresh and free from any defects, foreign matter and chemical residue.

Harvested plants should be rapidly cooled as soon as possible to storage temperature (0–2°C) without freezing. A high relative humidity (90–100%) is important especially during the pre-cooling phase. If not stored under these conditions, Chinese broccoli will quickly dry out and wilt, becoming unsaleable.

Economics of production, Key contacts, Key references, and Key statistics

See Chinese chard.

Chinese cabbage

Bruce Tomkins

Paul Daly

Introduction

As the name suggests, Chinese cabbage (*Brassica rapa* var. Chinensis) appears to have originated in China. The earliest known records are from the fifth century, which suggests that it arose from a cross between Pak choi (*Brassica rapa* var. Chinensis) and turnip (*Brassica rapa* var. rapifera).

The term 'Chinese cabbage' is used to describe a wide range of brassica crops, both loose leaf (with or without flowers) and those which form a dense head. It is the heading types, *Brassica pekinensis* or *B. rapa* var. Pekinensis, which will be considered here. Depending on cultivar it can vary substantially in appearance, from the short, squat wong bok types to the long, slender rocket or michihili types.

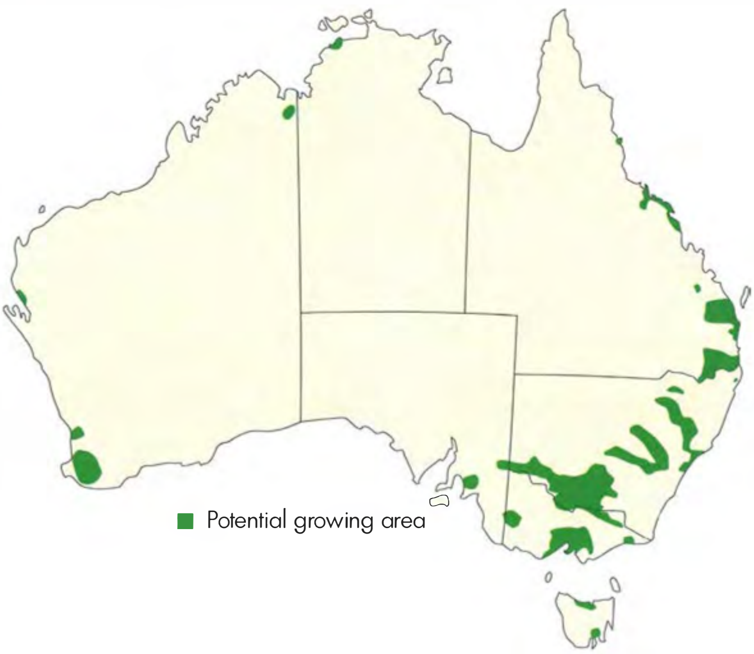
Chinese cabbage is the most frequently eaten vegetable in Asia. Around 40 million t are consumed in China and 1 million t in Japan each year. It is commonly eaten as a freshly cooked vegetable, for example in stir fry dishes, and is often further processed as a brined product or used in pickles such as kim-chi.

Chinese cabbage has been grown successfully in all Australian states by experienced brassica vegetable growers, using the same sort of cultural practices as for their existing crops. Major pest and disease problems are similar to those which affect other brassica crops. Most can be minimised by growing the proper cultivars at the correct time of the year and by using appropriate cultural and pest management. Perhaps the biggest challenge to producers for optimising niche marketing opportunities is to extend production into the colder months and so supply Asian markets during August to October. Export quality Chinese cabbage is scarce at this time.

There appear to be substantial opportunities to increase sales of Chinese cabbage on both domestic and export markets as a fresh and minimally processed product and in a brined or pickled form.

Markets and marketing issues

Australia's increasing Asian population and the 'Asianisation' of Australian diets has rapidly increased the demand for Asian vegetables. Major supermarkets



report that this is the fastest growth area in the fresh produce department and demand is out-stripping supply. Exporters of Chinese cabbage are having problems in sourcing long lines of supply and have been unable to meet some orders. Although the domestic market for Chinese cabbage appears to be increasing, most new growers are looking to export markets. Exports of Chinese cabbage from Australia have increased from $2.5 million in 1987–88 to $6.5 million in 1995/96. A large proportion is exported to Hong Kong (48%), Singapore (32%) and Taiwan (12.5%). Of the $6.5 million in exports, 59% was exported from Western Australia, 35% from Queensland and 4% from Victoria.

Australia's best time for selling brassica vegetables in Asia is from April to October. However this can vary substantially between countries and between years. Most markets for Chinese cabbage are still considered niche markets which are subject to factors such as local weather, particularly typhoons which can cause severe shortages at times. Growers interested in the export of Chinese cabbage need to consult with exporters well in advance to identify market opportunities and to ensure their product meets the export market's specifications. Singapore prefers 1 to 1.5 kg heads while Hong Kong will take heads of up to 2 kg.

At this stage substantial market research is required and some is under way to find new market opportunities for Australian Chinese cabbage. These include Malaysia, Indonesia, South Korea, Europe and Taiwan.

There is also potential for value-added products both on local and export markets through minimal processing, brining and pickling.

Production requirements

Temperate or cold-tolerant Chinese cabbage cultivars prefer temperatures between 13 and 20°C. However cultivars prone to bolting, particularly michihili types, may require warmer temperatures. Where temperatures frequently exceed 35°C, tropical or 'cold-sensitive' cultivars need to be grown. Under these conditions temperate cultivars are unlikely to form heads and are susceptible to disease. In general, Chinese cabbage can be grown in temperate and tropical climates, given adequate rainfall or irrigation. It is a shallow-rooted crop and does not tolerate drought.

Chinese cabbage require deep, well-drained soil because it is susceptible to root rots. It has been grown successfully on a range of soil types from light, sandy loams to quite heavy loams. A soil pH of 5.5 to 7 is ideal and lime should be applied if the pH is below 5.5, as calcium and other nutrients may be unavailable to the plants at low pH. Liming may also reduce the effect of clubroot if that disease is present. A fine, well-prepared, raised bed can help to prevent soil compaction, improve drainage and improve air circulation around the base of the plants, which will reduce the incidence and severity of diseases.

About the authors

Bruce Tomkins is the Leader of the Postharvest Technology Team at the Institute for Horticultural Development, Department of Natural Resources and Environment, Victoria (see *Key contacts* for address). He has over 20 years of research experience and has successfully led a number of projects on the postharvest handling, packaging, processing and storage of a range of Asian vegetables.

Paul Daly is a project scientist with over six years of experience in postharvest horticulture. He was responsible for a recently completed RIRDC project 'Developing a sustainable Asian vegetable industry in East Gippsland' which centred on the production and storage of Chinese cabbage.

Chinese cabbage cvs. 'Yuki' and 'WR Green' 60, East Gippsland

Proper irrigation of Chinese cabbage will increase yields and help to prevent nutritional and physiological disorders. Direct-drilled crops require watering every day until the seedlings emerge. Frequent watering may be necessary during growth and development. Measurements of soil moisture with potentiometers or other devices should be made regularly to determine the need for irrigation. Proper watering is particularly important during head formation. Inadequate watering will substantially reduce yield and may contribute to disorders such as tipburn while too much water during head formation can cause root death and poor quality heads.

Varieties/cultivars

Cultivar evaluation trials have been conducted in Western Australia, South Australia, Tasmania and most recently in Victoria. Most work was based on marketable yield and tolerance to disorders although Victorian studies also determined the relative storage potential of all cultivars tested. The performance of individual cultivars varied considerably between States and planting times. Overall, bolting was a major problem where attempts were made to extend the growing season into cooler months and the michihili types were far more susceptible to bolting than the wong bok types.

In Western Australia the cultivars most tolerant to gomasho and bolting were the wong bok types 'WR Green 60', 'RS1446' and 'China Pride'. Trials in Tasmania showed the wong bok cultivars 'RS1446', 'China Pride' and 'WR 60' were most tolerant to internal rots and gomasho and provided the highest marketable yields. The wong bok cultivar 'Hong Kong' is recommended for winter and spring plantings in South Australia and showed resistance to bolting and tip burn. In Victoria a range of varieties were planted between early autumn and early winter. All late plantings bolted except for the cultivars 'Cream' and 'Manoko' which produced a 60% marketable yield. For early to late autumn plantings 'Yuki', 'Treasure Island' and 'WR Green 60' (all wong bok types) were the best performed varieties and these also did well in storage trials except that WR Green 60 showed evidence of chilling injury after seven weeks of storage at 0°C.

Key statistics

Exports by State 1995/96 $A'000 (FOB)

Victoria	263
NSW	149
QLD	2256
SA	1
WA	3847
Tasmania	0
Aus. total	6516

Production by State 1995/96

	Area (ha)	Production (t)
Victoria	90	1233.6
NSW	26	646.9
QLD	132	3171.4
SA	77	133.0
WA	109	3260.2

Cultural practices

Chinese cabbage can be either sown directly from seed or transplanted into a fine, well-prepared, raised seed bed. When sown from seed it is common practice to sow two to three seeds per station 12–15 mm deep in the soil and thin by hand after germination. It is recommend to sow seed at a rate of 500–750g/ha which will give a plant spacing of approximately 35 cm. Common plant spacings are 30 cm between plants and rows, 37.5 cm between plants in the same row and 30 cm between rows to produce heads around one kg and a row spacing of 40 cm with a plant spacing of 35 cm for wong bok and 30 cm for michihili types to produce heads between 1 and 1.8 kg.

Transplants are generally raised in a greenhouse or polyhouse for three to four weeks before planting in the field. Transplanting is initially more expensive than direct seeding but has some compensatory advantages. Use of transplants helps to mitigate adverse environmental factors during early seedling growth such as unseasonably cold temperatures which may induce bolting. Additionally, direct seeding requires more seed, extra labour for thinning, larger scale irrigation and more pest, disease and weed control.

Chinese cabbage requires large amounts of fertiliser, particularly the macronutrients nitrogen, phosphorus and potassium. Fertilisation often begins with an application of animal manure at least two weeks before planting. V.Q. Nguyen has recommended that a fertiliser with an N:P:K ratio of 5:5:5 should be broadcast at a rate of 1.5 t/ha before planting. After crop establishment, regular applications of N and K fertilisers are required with applications through the irrigation system (fertigation) being the most efficient. It should be noted though that excessive use of nitrogen has been linked to an increase in the incidence and severity of several disorders including tip burn, gomasho and soft rots. High applications of phosphorus have also been linked to an increase in the incidence of gomasho.

Key messages

- Domestic consumption growing rapidly
- Exports have increased 275% in 7 years
- Grows in temperate and tropical climates
- Over 40 million t eaten in China each year
- Stores for many weeks

Chinese cabbage matures rapidly especially during warm periods with wong bok types tending to mature earlier than michihili types. For example, a range of cultivars grown in South Eastern Victoria took 65 to 80 days from planting to harvest in early autumn and 97 to 117 days when planted in mid-autumn. Heads should be harvested when they are well filled and firm but not very hard and before flower stalk initiation.

Pest and disease control

In general, Chinese cabbage is susceptible to a wide range of pests and diseases which affect other cruciferous crops. Some of the more important include the bacterium *Xanthomonas campestris* which causes black rot, club root caused by the slime mould fungus *Plasmodiophora brassicae*, turnip mosaic virus (TuMV), cauliflower mosaic virus (CaMV), diamondback moth (*Plutella xylostella*) and cabbage aphid (*Brevicoryne brassicae*). Only clubroot and diamondback moth will be discussed here.

Clubroot is a serious disease of cruciferous plants and Chinese cabbage is highly susceptible. The fungus is soil-borne and enters the plant through the root hairs on young plants or through wounds on the roots or stem, causing the roots to become

Chinese cabbage cultivar evaluation trials, East Gippsland thick and distorted. Severely affected roots cannot absorb water and minerals from the soil and produce stunted plants which usually fail to produce a marketable head. Clubroot spreads readily through infected seedlings, in water and in soil attached to equipment and the boots of workers. It is a very hardy organism and can survive and remain infectious for at least 20 years in the absence of a suitable host.

Diamondback moth is the most important world-wide pest of brassica crops. It is believed to have originated in the Mediterranean area and it can disperse over long distances. In the caterpillar phase it eats the leaves of cruciferous crops, often causing a skeleton effect where most of the green tissue is removed leaving the mid-ribs and veins. It attacks crops at all stages of maturity from the seedling stage on and can cause widespread loss.

Adult moths are about 9 mm long and greyish brown with three light brown to white triangular markings on the top edge of the forewing which form a diamond shape when the wings are closed and the moth is at rest. The smaller caterpillars feed on the green mesophyll cells from one side of the leaf often leaving the opposite leaf surface intact, creating a distinctive 'window' effect. If disturbed the caterpillars drop from the leaf and hang suspended from fine silken threads. When mature, they spin a flimsy silken cocoon on the surface of the leaf and pupate within it. The adult moth emerges after a week or two.

For a comprehensive overview of the pests and diseases of Chinese cabbage and current control recommendations see Daly and Tomkins (1997).

Harvest, handling, and storage

Chinese cabbage heads should be harvested when they are well filled and firm but before the flower stalk starts to develop substantially. It is usually harvested by hand with the outer leaves trimmed off and the butt trimmed flush with the outer leaf bases. They should be harvested in the cool part of the day and handled carefully as they are very easily damaged. Heads should be rapidly cooled to as close to 0°C as possible immediately after harvest and this temperature should be maintained during storage and distribution.

If Chinese cabbages are properly precooled, stored at 0°C and protected from moisture loss they can be effectively stored for many months. Water loss can be prevented by providing a high humidity storage environment. A simple means of achieving this is to store heads in a plastic bag with the top folded over. Recent research has shown that storage life can vary substantially between cultivars and more research is required in this area. Some cultivars appear to suffer a form of chilling injury expressed as browning of leaf mid-ribs and some are more susceptible to storage rots than others.

Economics of production

Chinese cabbage production is best suited to existing brassica vegetable producers who wish to diversify. It does not require any specialised equipment apart from that used for the production, handling and storage of more traditional brassica crops such as cabbage, cauliflower and broccoli. Costs of production of Chinese cabbage are being prepared under the State Government of Victoria and RIRDC joint project 'Access to Asia' and will become available to the public shortly.

Harvesting Chinese cabbage for seafreight export, East Gippsland

Paul Daly assesses the quality of Chinese cabbage after prolonged storage.

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Chinese chard

Stephen Moore
Wendy Morgan
Mandy Chew

Introduction

Chinese chard (*Brassica rapa* L. var. *chinensis*) is a biennial or annual plant available in many parts of the world. Chinese chard is native to eastern Asia and has been cultivated for thousands of years. Many names are used for Chinese chard, such as Chinese white cabbage, Chinese mustard, bok choy and pak choi. Chinese chard is unlike other cabbages because it does not form a true head.

Chinese chard has been grown successfully and is available in all Australian States. It has characteristic two-toned leaves with bright and/or ivory white leaf stalks topped with dark green leaves. The only exception is Shanghai Chinese chard, which has light green leaves and leaf stalks. The flowers of Chinese chard are bright or pale yellow about 1 cm long. The seeds are round, dark brown and weigh approximately 3 g/1000 seeds.

In Australia, Chinese chard is a very important leafy vegetable making up about 10% of the total Asian vegetables used by volume, second only to Chinese cabbage. Chinese chard is easy to grow, produces relatively high yields and is very nutritious.

Markets and marketing issues

Chinese chard is available in markets all over world and is found predominantly in Asian markets. Markets for it are large because it is used in most Asian meals. The average annual wholesale price for Chinese chard in Japan is $4.50/kg (based on Yen 75= $Aus1.00). The domestic market had a higher priority than the international market.

Chinese chard is available at most major wholesale markets and Asian grocery stores throughout the year in Australia. In Sydney, the average wholesale price range is between $0.50 and $1.00/bunch. Similarly, the Melbourne Market average wholesale price was between $0.50 and $1.00/bunch. The average retail price in and around Melbourne was between $1.50 and $3.00/bunch.

Chinese chard has been given a high industry priority for expansion for the Australian fresh market on the basis of existing market and production information. It was also listed as one of the top five Asian vegetables for the three major trading channels: Asian restaurants, Asian grocery stores and Australian supermarkets.

Production requirements

Most Chinese chards are essentially cool-season crops, preferring uniform conditions that are moist and in full sunlight for optimum plant growth. The ideal temperature for growth is between 15 and 20°C, but there are varieties available for warmer weather. Diurnal variations of 5 to 6°C appear to improve plant vigour. High temperatures and long days tend to induce bolting, which is also known as premature flower stalk formation. Most varieties tolerate light frosts and the Shanghai Chinese chard is able to tolerate more severe frosts for short periods.

Chinese chard can be grown in a wide range of soils, but prefers fertile, high organic matter and moisture-retentive soils (e.g. rich loamy soil). The ideal soil pH is around 6.5–7.0 and lime should be added if it falls below a pH of 6. Adding lime to the soil profile is also thought to help reduce the incidence and severity of clubroot if present. Soft rots can also be prevented by preparing raised beds with improved drainage and improved air circulation.

Chinese chard is shallow-rooted like most other brassica crops and requires frequent watering for optimum growth. Lack of moisture at any stage can promote bolting and poor quality plants. The water should be applied lightly and frequently, to reduce the chance of leaching soil nutrients and encourage healthy plant growth. Young plants should be protected from the wind as even the leaves of mature plants can be damaged by strong winds.

About the authors

Stephen Moore is the Horticultural Industry Development Officer at Geelong, Department of Natural Resources and Environment. He has three years experience, specialising in Asian vegetable agronomy, pests and diseases, field trials and extension.

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Mandy Chew is the Vegetable Industry Technology Transfer Officer at the Institute for Horticultural Development Knoxfield, Department of Natural Resources and Environment. She has three years experience, specialising in Asian vegetable markets, wholesale market intelligence, newsletter construction and distribution.

See *Key contacts* for authors' addresses.

Key statistics

Statistics are not available on Australian/principal State production, imports, exports for Chinese chard, mainly because of commercial sensitivities.

Varieties

There is much confusion over the different types of Chinese chard. To simplify the problem they have been divided into four major groups, based on appearance.

1) The 'Chinese White Bok Choy' is a sturdy-looking variety with thick green leaves curling outwards. The leaf stalks are bright white, curved slightly and thin. The plants tend to reach a height of about 30 cm at maturity. Although they vary in their cold tolerance and have a tendency to bolt, they are vigorous. An example of a highly productive hybrid is 'Joi Choy'.

2) The green leaf stalk type, 'Shanghai Bok Choy', has leaf stalks which are light green in colour, broad, flat and widen at the base like the other bok choys. They are harvested at a height of around 15 cm. They are very hardy and able to grow all year round at temperatures between 18 and 21°C. A popular variety is 'Mei Qing'.

3) The 'soup spoon' type has thinner leaves and leaf stalks. The leaves are lightly cupped and ladle-like while the leaf stalks are white and semi-circular. They grow to a height of 45 cm and there are shorter forms available. They are vigorous and versatile with good tolerance to cold and heat. Varieties include 'Japanese White Celery Mustard', 'Nikanme', 'Seppaku' and 'Tai Sai'.

4) The 'squat' or 'Canton' variety is the most compact. It is short with convoluted dark green leaves. The leaf stalks are white, short and thick. They can be harvested as baby bok choy or left to reach maturity. They are best adapted to warm weather and very apt to bolt in the cold weather.

Agronomy

Most Asian vegetable producers grow their crops intensively on relatively small farms of only 1–5 ha. Some southern Australian Asian vegetable growers have intensified their production of Asian vegetables by growing in polyhouses. Polyhouses stop winds, increase light intensity within the structure and increase air temperature by several degrees, depending on the climate outside the polyhouse. Protected cropping assists growers to increase yields, improve quality and extend the time crops can be grown successfully. In addition, such vegetables are said to be more tender and less fibrous than when compared grown outdoors.

Chinese chard can be sown directly or transplanted into a well-prepared, raised bed. Spacing varies according to the type, variety used and size of plant required. The large types like 'Chinese White' require 45 cm between each plant. The average within-row spacing for medium-sized varieties would be 18 to 23 cm and the small varieties, 2.5 to10 cm apart. Rows should be 18 to 30 cm apart.

Seedlings can be raised in a heated environment at a minimum temperature of 18°C, and hardened off before transplanting. Transplants reduce the time plants are grown under adverse conditions, reducing the chance of bolting and the time to harvest. Commercial production of Chinese chard in greenhouse and polyhouse structures has been successful all year round. The seed is usually germinated in seedling trays at about 20°C and after emergence the temperature is reduced to about 10°C or less. The seedlings are generally transplanted in the greenhouse structure after 25 to 30 days of growth and if possible the temperature is raised to about 20°C a week after planting.

During late autumn to early spring when the weather is cool, only cold-tolerant types and cultivars should be grown, such as the Chinese White Bok Choy and soup-spoon types. Heat-tolerant varieties such as the Shanghai Bok Choy and Canton types, can be grown during summer conditions or in heated polyhouses.

On sandy or light soils, the highest yield of Chinese chard has been achieved with 200 kg/ha nitrogen and at the closest plant spacing of 0.1 m × 0.3 m. The plant spacings used were 0.1 m, 0.2 m, 0.3 m and 0.4 m with 0.3 m between rows. At 400 kg/ha of nitrogen yields actually decrease and the incidence of soft rot damage increases. The fertiliser and spacing does not significantly affect the time Chinese chard takes to reach maturity.

Pest and disease control

There are many weeds, insects and diseases that can reduce the yield of any vegetable crop. There are very few chemicals registered for use on Asian vegetables in Australia. Best practice management systems (e.g. IPM – Integrated Pest Management) should be adopted when controlling weeds, pests and diseases. Weeds compete for water, nutrients and space and must be controlled in the early stages of growth, because Asian vegetables are relatively slow-growing, especially when direct seeded. Hand weeding and dutch hoeing are commonly used for weed control. A pre- or post-transplant herbicide may be beneficial in reducing the competition from weeds.

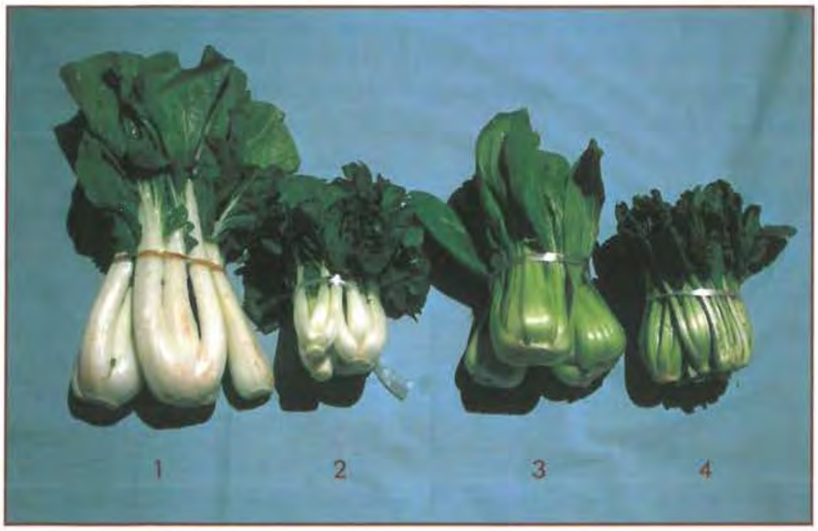
The major diseases of concern when growing Chinese chard, are as follows:

Clubroot (*Plasmodiophora brassicae*) is distributed worldwide and is a major disease of all brassica crops. The soil-borne fungus develops slowly, entering the root hairs and forming club-like malformations on the roots. The plants become stunted and wilt during warm weather. Good management practices can help control clubroot. Common practice is to use a combination of long plant rotations with non-hosts, maintenance of a soil pH at 7.3 or above, fumigation, sanitation and maintenance of a high soil organic matter. Farm hygiene is very important because it helps prevent the movement of clubroot from infected soil into clubroot-free areas. Future control measures may use combinations of chemicals, nutritional programs, rotation and clubroot resistant varieties.

Downy mildew (*Peronospora parasitica*) is also a worldwide major disease of brassica crops. Infected leaves develop purple, yellow or brown patches on the upper surfaces and white to grey downy fungal growth underneath. Older leaves show signs of small necrotic areas that look like small black specks. During moist conditions the specks may enlarge to form large black patches. Plants should be kept well ventilated to reduce the humidity and the risk of downy mildew. Overhead irrigation should be avoided where possible. Cruciferous weeds should be controlled.

White rust or white blister (*Albugo candida*) is distributed worldwide and is a less common disease of brassica crops, radish and other mustards. Symptoms include small circular spots raised on both sides of the leaves. On the underside of leaves, a mass of white powdery spores develops. Yellowish to green spots also develop on the top surface of leaves. White rust can be controlled by removing any cruciferous weeds, long plant rotations with non-hosts and by ensuring that all plant residues are completely decomposed before transplanting new crops.

Chinese chard



1. Chinese chard, 2. Baby Chinese chard, 3. Shanghai Chinese chard, 4. Chinese flat cabbage (tatsoi).

Edema (oedema) is a physiological disorder with symptoms that resemble small warts; these can join together to form a ridge. Usually they are found on the underside of leaves. The disease can occur when soil is warm and wet, but the air temperature is cool. The disease is favoured by prolonged periods of high humidity, which can occur in poorly ventilated polyhouses or glasshouses. Control of the disorder can be achieved by not allowing the soil to become too wet and in polyhouses by having good ventilation.

The major pests of concern when growing Chinese chard, are as follows:

Aphids (*Brevicoryne brassicae*) can feed on a large number of plant hosts. They have piercing and sucking mouth parts which they use to get sap from plants. Aphids can be found underneath leaves, and where they like to feed on new shoots and buds. Parts of the plant may wilt, look distorted and curled. The aphids can also act as vectors for a number of viruses (e.g. turnip mosaic), causing even greater damage. Cruciferous weeds should be controlled as they host aphids.

Caterpillars (the larvae of moths and butterflies) will attack and severely damage brassica crops. Examples include the large and small cabbage white butterflies (*Pieris rapae*), the diamond back moth (*Plutella xylostella*) and the green looper (*Chrysodeixis eriosoma*). Many chemicals have been used to control caterpillars and resistance to some chemicals has developed, particularly for diamondback moth. Appropriate strategies such as IPM should be used for controlling caterpillars and in particular diamondback moth.

Snails and slugs (Class Gastropoda) are attracted to the succulent leaves of all brassica crops. They are of major concern to growers, because they eat whole young plants and can severely damage older plants. The greatest damage occurs during mild and damp weather, when snails and slugs are most active. Snail and slug pellets are the most commonly used form of control.

Harvest, handling and packaging, storage, postharvest treatments and processing

Preservation of food has been essential in Asia, to ensure that food was available during shortages such as those associated with a lack of production during winter. Vegetables are preserved by fermentation, pickling, drying, salting and adding sugar.

Chinese chard is usually hand-harvested at the base with a knife. Any old or damaged outer leaves are trimmed off and the butt trimmed flush at the base. There should be no blemishes or defects of any kind. Chinese chard can be ready to harvest 35–55 days after sowing. Yields average about 15 t/ha. Chinese chard should be harvested well before the outermost leaves turn slightly yellow, which is before the plant fully matures and becomes fibrous. The plants can bolt before maturity and should be harvested when there is any evidence of a flower stalk.

Chinese chard should be harvested in the cool part of the day and handled carefully as they are prone to physical injuries, such as bruising of the leaf stalk. As it is susceptible to wilting, Chinese chard should be used fresh as possible. In Australia, Chinese chard are bunched in groups of 2–3 plants. Bunching is not a good practice as the string/band used to tie the bunch together causes damage. The white-stemmed varieties can be stored at 0–1°C with 85–100% humidity for a week while the green-stemmed variety can be stored for a little longer. Chinese chard can last up to 30 days in modified atmosphere packaging (MAP). Little is known about the effects of type and cultivar on storage life.

Economics of production

Chinese chard has mainly been produced in Australia by Asian (Chinese and Vietnamese) vegetable growers and some traditional brassica growers, who have diversified into new crops. Equipment used for the production of other more traditional brassica crops such as cabbage, cauliflower and broccoli, can be used to grow Chinese chard. However, potential growers should to be aware that Chinese chard is fast growing and may require more labour at harvesting than the more traditional crops. Accurate costs of production analysis for Chinese chard, like most other Asian vegetables, are not available.

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Chinese flowering cabbage

Stephen Moore
Wendy Morgan

Introduction

Chinese flowering cabbage (*Brassica rapa* L. var. *parachinensis* Bailey) is a native of the Chinese Kwangtung Province and is grown and consumed virtually all year-round throughout south-east Asia. It belongs to the Crucifer family and has other common names, such as tsoi sum and choy sum. Because of its pleasant taste and cooking qualities, it has become a most common leafy vegetable in Hong Kong.

The leaves of Chinese flowering cabbage are large, elliptical and green. The plant has about seven or eight leaves when it flowers, the largest leaves being on the outside. The flowering stems are uniform in diameter and slightly grooved from tip to base. The whole plant can be eaten, including the flowers, which are normally yellow. The height of the plant varies from 20 to 30 cm. The bulk of the root system occurs within a depth and radius of 12 cm from the stem. The average spread of the plant varies between 15 and 45 cm.

Marketing and marketing issues

Chinese flowering cabbage is available in Australia at most major wholesale markets and Asian grocery stores throughout the year. The wholesale price range is between \$0.50 and \$1.00/bunch. Similarly, the Melbourne Markets average wholesale price was between \$0.50 to \$1.30/bunch. The average retail price in and around Melbourne was between \$1.00 and \$1.50/bunch.

Chinese flowering cabbage is one of the best selling Asian vegetables in the three main retail outlets: supermarkets, Asian grocery stores and Asian restaurants. In addition, it was listed as one of the top five Asian vegetables under production in New South Wales and Victoria.

Production requirements

Chinese flowering cabbage is a cool-season crop and prefers uniform conditions that are not too dry, wet or shady. It is of higher quality when grown in cool weather because the shoots are thicker, more tender and sweeter. Chinese flowering cabbage varieties are generally not frost-tolerant. There is a purple flowering variety which can survive temperatures down to about –5°C.

The seasonal changes in temperature will generally determine when a particular crop can be grown and may differ markedly with the variety. It can be grown all year round where seasons are not extreme. Chinese flowering cabbage tends to bolt in summer before the plant reaches sufficient size, resulting in spindly shoots.

Chinese flowering cabbage is shallow-rooted like most other brassicas and requires frequent watering for optimum growth. Watering once or twice a day will produce good quality plants, regardless of the quantity of water applied. However, water should be conserved and applied frequently but lightly. The highest yield achieved was from watering twice a day at a rate that was less than one fifth of that used by many commercial growers in the locality.

The amount of water needed is influenced by soil type, with sandy soils draining very quickly and requiring more frequent watering than other soils. The ideal soil type for vegetable production is fertile and has good drainage along with a high organic matter content. The soil pH should be between 6.0–7.0 and should not fall below 5.0.

Varieties

Chinese flowering cabbage varieties are classified by the number of days from sowing to harvest and their susceptibility to bolting prematurely. For example, 40 days (sze sap yat), 50 days (ng sap yat), 60 days (luk sap yat) and 80 days (bat sap yat). In addition, the flowering stem colour that ranges from white to light green will help determine the variety.

Chinese flowering cabbage

Agronomy

The rates of fertiliser required for optimum crop development can differ markedly between soil types. Soil testing is the best way to determine the elements needed for crop development. Two suggested mixes of fertilisers for Western Australian soils, are as follows:

1. Sandy Soils. Base dressing of poultry manure (50 m^3/ha), superphosphate (1.25 t/ha) and trace elements. Two side dressings of Agran 34-0 and muriate of potash (each at 150 kg/ha) should be applied about one and three weeks after emergence.

2. Medium and Heavy Soils (Poor fertiliser history). Base dressing of superphosphate (2tonne/ha), muriate of potash (600 kg/ha) and trace elements. Two side dressings of Agran 34–0 (300 kg/ha) should be applied about one and three weeks after emergence.

Nitrogen fertiliser can improve Chinese flowering cabbage yields. Field trials have shown that the marketable fresh weight yield (46.1 tonne/ha) of Chinese flowering cabbage was the highest at a spacing of 10 × 10 cm with 200 kg/ha of nitrogen. The yield is over double that of the average yields in Malaysia which are between 11 and 20 t/ha. At other spacings (i.e. 20 × 30 cm, 30 × 30 cm and 40 × 30 cm) the maximum yields were reached at about 100 kg/ha of nitrogen.

Chinese flowering cabbage can be difficult to grow unless the correct variety is matched with the climatic conditions. Germinating seeds at high temperatures may help to prevent premature bolting. Seed can take 3 to 9 days to emerge from a sowing depth of 0.6 cm during autumn and 3 to 7 days in summer. The size of the seed is also very important. The larger seeds give more vigorous seedling growth and the plants came to maturity earlier than those from the smaller-size groups. The recommendation was then to discard any seed under 0.118 mm in diameter.

Key statistics

Statistics are not available on Australian/principal State production, imports, exports for Chinese flowering cabbage mainly because of commercial sensitivities.

Chinese flowering cabbage can be sown directly or transplanted in rows about 30 cm apart and spaced/thinned to about 10–20 cm. Spacings between plants are generally 8–20 cm, allowing wider spacings for larger varieties. In commercial greenhouses, plants are direct sown in rows 18 cm apart and the seeds spaced at 2.5–5 cm. The seedlings are thinned close together so that they do not grow large and tough-stemmed. The highest yields were obtained at close spacings of 10 × 10 cm.

Pest and disease control

See Chinese chard.

Harvest, handling and postharvest treatments

Chinese flowering cabbage can be harvested from direct seeding in the field when fast-growing in as little as 30 days. The time of harvest of most Asian vegetables is critical for high quality produce. Harvesting in the cool of the morning is preferred because it reduces moisture stress, especially during summer. Once picked, many Asian vegetables are tied and bunched as whole plants into groups or bunches. The size of the bunches depends largely on the market requirements and the type of vegetable. Asian vegetables should be fresh and free from any defects, foreign matter and chemical residue.

Many vegetables should be rapidly cooled as soon as possible to storage temperature (0–2°C) without freezing. In general, a high relative humidity (90–100%) is important to prevent wilting especially during the pre-cooling phase. It is critically important that leafy Asian vegetables should be stored under these conditions throughout postharvest (even during transport) for a high quality product, otherwise it will quickly dry out, wilt and become unsaleable.

Chinese flowering cabbage is harvested as the first flower buds begin to open. The whole plant is cut at the base, bunched into bunches of ten to twelve and tied. The main stem should be long (10–15 cm) and thick in diameter (1.5–2.5 cm) at the base. Side shoots will develop after cutting the main stem and they can also be harvested. Chinese flowering cabbage should be presented free of roots and with or without flowers.

Economics of production, Key contacts and Key references

See Chinese chard.

Chinese waterchestnut

David Midmore

Introduction

Chinese waterchestnut (*Eleocharis dulcis* (Burm. f.) Trin. ex Henschel) is a tropical member of the sedge family and as its name implies it is an aquatic species. Plants consist of four to six upright tubular stems approximately 1.5 m tall. Vegetatively propagated, the corms (or tubers), the edible portion, are produced at the end of underground stems (or rhizomes).

A botanical novelty ten years ago, although in its wild form it was reputedly harvested by Aboriginals, it is now produced and marketed commercially in Australia, substituting for the importation of canned produce. For Australia, the Australian produce has the advantage of being marketed fresh (the tinned product lacks quality and consumer appeal) but it is only available over the period June to November, thereby limiting the effectiveness of import substitution.

Premium Australian waterchestnuts are > 4.0 cm in diameter (Photo 1), and better than those from traditional production zones in Thailand (*Suphanburi*), China (*Guai Lin*) and Taiwan (Tainan County); but according to connoisseurs, Australian produce at times lacks sweetness and tastes starchy. The crispy texture, which is retained after processing or cooking, is due to the presence of the ferulic acid-containing hemicelluloses in cell walls of the chestnuts. The product is favoured for 'fresh' stir-fry mixes, and currently the tinned form is used to supply this product line in supermarkets. It also forms the basis for heavily sweetened drinks in Asia, and is sold in syrup for use as a desert.

A tradition of production in Taiwan and China and the recent introduction of a canning industry in Thailand underpin the world trade in waterchestnut, and the US is the major importer of the canned form.

To assist new and prospective growers, an Australian Aquatic Vegetables Development Committee (Midmore, 1997) has been established to provide information on cooperative establishment of quality assurance, grading, marketing opportunities and coordination of planting and production goals.

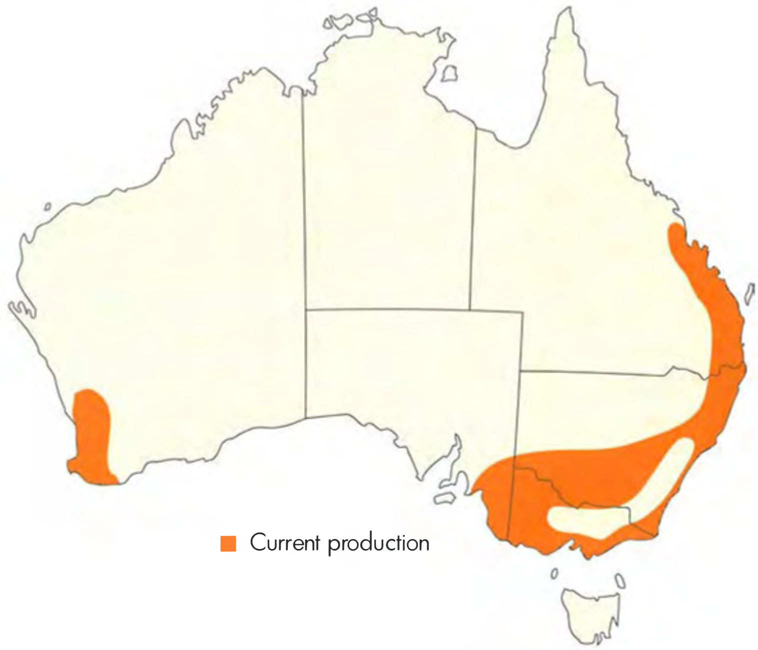


Photo 1. A sample of highly acceptable waterchestnuts.

Markets and marketing issues

Waterchestnuts are marketed in Australia in the fresh, frozen and canned forms. Frozen and canned forms are peeled; fresh chestnuts are sold with their skins (the lignified 0.75 mm thick peel) intact. In Asian wet markets fresh chestnuts are peeled by hand in quantities to satisfy demand. The fresh nature of waterchestnuts (ie. with approximately 80% moisture) necessitates their storage, transport and display under cool (<10°C) and humid conditions. The importance of this to retail markets cannot be over-emphasised.

Current levels of canned imports into Australia are unknown because ABS data are pooled with those of true chestnuts and retailers prefer not to divulge such information. Retail prices for canned chestnuts (approx. 90 cents/227 g [gross] tin) are similar to, or less than those in Asian countries—Singapore A$1.20/340g (gross); Thailand A$1.25/227g (gross)—and wholesale prices of canned waterchestnut in Australia (48 cents to 79 cents/230g [gross]) convert to $3.7 to $6.0/kg of net waterchestnut. Current retail prices of fresh Australian waterchestnuts range from $4.00 to $12.00/kg, which is highly competitive with the net retail cost of canned produce.

The current production in Australia is *ca.* 20 tonnes per year, with the bulk coming from Mackay and the balance from NSW and Victoria. Most product is marketed through supermarket chains, while small-scale production is sold via country markets. Production in Japan is on the decline (1600 tonnes in 1984 to 1200 tonnes in 1992) as it is in Taiwan (1200 tonnes in 1991 to 860 in 1995). The best retail prices are gained in Japan from September to December, ranging from A$9.0 to A$30.0/kg while in Taiwan retail price is quite stable at A$6.0/kg, double that of the farm-gate price. Australian production currently pales into insignificance compared with that of Japan and Taiwan, and with that of China which dominates the supply of canned and semi-preserved waterchestnuts to the USA. Approximately US $35 million as canned and US $8 million as semi-preserved product was imported to the USA in 1996. With an established and potentially larger national market, it is opportune to embark upon export ventures, especially now that the Australian industry draws upon four mechanised harvesting systems which considerably reduce the labour for the crop.

About the author

Professor David Midmore has been with Central Queensland University as Director of the Primary Industries Research Centre (see *Key contacts* for address) for two years. His previous research experience spans vegetable and staple crops in Asia and Latin America.

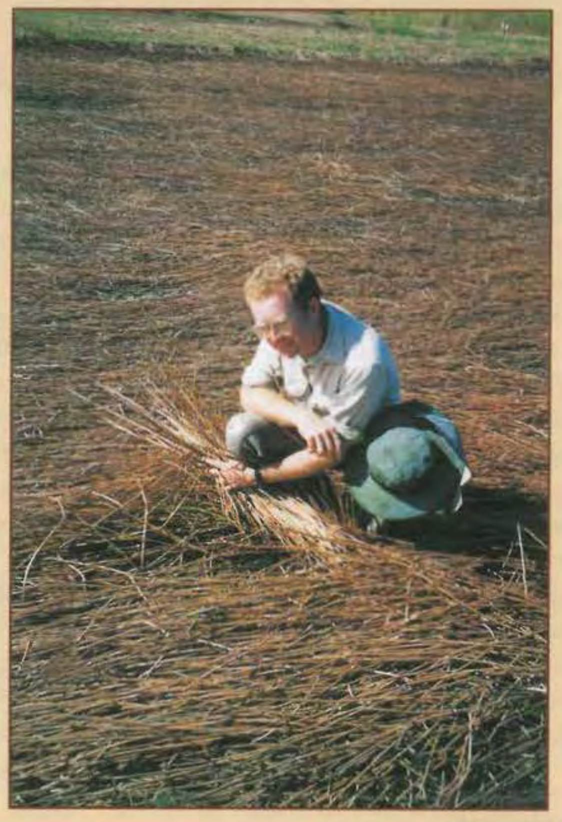
Sweeter than sugarcane—Gunning's Australian Waterchestnuts

Faced with the dilemma of splitting an already marginally profitable cane-farm in Mackay, the Gunning brothers, Greg and Patrick, decided in 1991 to sell most of their land and move into Chinese waterchestnut production.

Why waterchestnuts? Essentially, the idea to grow chestnuts arose from an article in the *Good Fruit and Vegetables* magazine that mentioned the crop, highlighting the intensive nature of production and the need for an assured supply of water. This fitted the bill for the Gunnings. Corms for the first year's planting were obtained from Western Australia and Brisbane and the 900 kg harvest was sold through a prior marketing arrangement with Woolworths in Brisbane. After two days of back-breaking harvest in the first season, the brothers drew upon their practical engineering experience (welding and oxyacetylene skills came in handy) to produce a prototype mechanised harvester to ease the burden of hand-harvesting.

The management of the first (and subsequent) crops was a learning experience, but with new ponds opened each year, harvests grew to the current production of 20 t/year. Choice of product identity and a registered logo and name (Gunnings Australian Waterchestnuts) led to a corporate image which, with adherence to quality as demanded by the market outlet, helped to establish and maintain markets.

Mechanical processing equipment for washing, cleaning and grading ensures product quality, and provides casual local employment. Information about the product, especially about the best means of storage, and recipes for unaccustomed purchasers (on the box for retailers and on the polyethylene bags for consumers) has raised awareness of the produce. But the Gunnings agree that more promotion of the corms as a cooked vegetable, sweet or salads ingredient, is still needed.



Production requirements

A puddled or clay-base soil, along the same lines as for paddy rice, is ideal for waterchestnut cultivation (Photo 2). Highly porous and sandy soils are not suitable, for ponds drain rapidly, and must be lined with industrial quality (200–400 micron) polyethylene sheets if they are to be used for waterchestnuts.

Although clay soils favour water retention and puddling, they present serious drawbacks for some harvest systems, particularly since they need more labour for hand-harvesting. In such instances, producers may add sand or composted filter press mud (from sugar mills) to clay soils to ease the harvest burden.

Since the crop is grown in an almost entirely flooded condition, flat or terraced land is necessary. Access to irrigation that will replenish at least the evaporative demand (measured as pan evaporation at standard weather stations) is essential if rainfall during the cultivation season does not exceed evaporation. Often an inland species in the wild, cultivated waterchestnut does not tolerate irrigation water salinity values of greater than 3.3 dS/m without loss of germination and corm yield.

Key statistics

	Production (t)	Retail price ($AU/kg)	Imports ($AU million)
Australia	20	4-12	no data
Taiwan	860	5	1.6[a]
Japan	1200	8–30	4.0[a]
China	no data	0.5–2	–
USA	Negligible	no data	47.0

[a] Estimate based upon recent decline in local production.

The crop is customarily grown in a sub-tropical to temperate climate, planted in the spring where the growing temperature of 15°C–25° can be maintained, and senescing in autumn in response to plant maturity rather than as a response to low temperature. Generally a 220 day frost-free period is necessary for natural completion of the crop cycle. High daytime air temperature (ca 30°C) favours growth of the crop. Current and potential production areas in Australia are demarcated on the accompanying map.

Varieties

The wild form of waterchestnuts, with small hard corms (approx 1–2 cm diameter), grows extensively in South Asia and much of Oceania. The cultivated form has larger corms, selected in China for their sweetness and juiciness.

On various occasions superior cultivated lines have been imported to Australia. A summary of the officially reported imports and acquisitions is shown in Table 1.

The distinction between varieties currently cultivated is all but lost, and a project is under way to identify cultivated lines using the technique of DNA-based genetic finger-printing. This is of primary importance to maintain quality standards for local and export markets. Prospective growers should be aware of the genetic identity of the material to be planted. It is possible that some lines are more suited to the climatic conditions of Victoria as opposed to those of Queensland, but without clear identification of lines this cannot be confirmed.

Agronomy

Land preparation comprises construction of ponds, or paddies, the dimensions of which should relate to the proposed form of harvesting. One third to one half of complete fertiliser (total fertiliser: 200–350 kg N/ha; 120 kg P_2O_5/ha; 170 kg K_2O/ha) is applied and incorporated in the dry soil before planting, and may be replaced by an earlier application of organic manure at rates of *c*. 12 t/ha. The soil is then well watered but not flooded. Sound corms, preferably large (for circumstantial evidence suggests that planting larger corms leads to greater harvest and large-sized produce) and with a viable terminal bud, are used as planting material. The terminal bud is face-up at planting. Corms may be directly planted to the field, or planted at high density (corms almost touching each other) in a nursery for production of transplants. Corms sprout as ground and water temperature rise above 13°C, and this may be hastened under nursery conditions in cooler climates by the judicious

Table 1. Origins of known imported lines of Chinese waterchestnut

Year	Importer	Local name	Origin/Source
?	Allan Hibberd		Botanical garden at Mt Coot
1988	Allan Hibberd	Black skin	Taiwan to Qld
1988	Allan Hibberd	Red skin	Taiwan to Qld
1989	Dallis Raynor	Dallis	Taiwan to Qld
1989	Hans Erkin	Matai 'supreme'[a]	Chinese farmer in Qld
1988	Werner Leutert	Hon Matai	China to USA (PI 106274) to WA
1995	Greg Gunning		Thailand to Qld
1994, 1996	Greg Gunning		China to Qld

[a] Given by Peter Gersteling

use of clear polyethylene sheet covers. Following direct planting to the wet field, at a depth not exceeding 4 cm, the field is flooded and allowed to drain naturally. Further flooding may be undertaken within three weeks, or when stems are 20 to 30 cm tall. Deeper flooding will usually cool the environment around the corm and delay germination, hence shallow flooding is to be favoured in southern climates, both for plant establishment and during the grand period of growth.

Corms in nurseries are treated similarly to those in the field, and germinate approximately 10 days after planting. They are transplanted into moist or flooded ponds when they reach 20 to 30 cm height, and the tops may be trimmed before transplanting if to tall. Crops from transplants in temperate climates will usually mature 5–6 weeks earlier than crops directly planted to the field on the same date as transplanting. This difference diminishes where temperature, especially at night, is more equable year-round.

Plant spacing in the field depends largely upon climate and planting date (more southerly climates and/or later planting reduces opportunity for rhizome and daughter plant production, therefore should be at closer spacing), but soil fertility and level of fertiliser input will govern plant vigour, and plant spacing should be adjusted accordingly. On average between three and five transplants (or corms) are planted per one square metre, with a triangular arrangement often preferred.

Once established, the crop is continually maintained in a flooded condition, even during the application of the remainder of the inorganic fertiliser, which should conveniently be split and applied eight to ten weeks after planting as the secondary (daughter) plants appear, and just before the development of corms. The application rates of fertiliser is very site-specific, depending upon the natural and organic manure sources of nutrients. Seeding the pond with the water fern *Azolla* can reduce the overall need for N fertiliser in the subsequent crop. The nitrogen-fixing fern can fix about 50 kg N ha/yr. *Azolla* is also seeded with the intention of reducing excess soluble nitrogen in ponds and pond water, but the validity of this practice has not been verified. As a rough guide, a waterchestnut crop removes 240 kg N/ha, 33 kg P/ha, 460 kg K/ha, 12 kg Ca/ha and 50 kg Mg/ha; approximately one third to one half of this removal is in the corms. These nutrients must be replenished to minimise 'mining' of soil nutrients. Nitrogen fertiliser is best applied in the NH_4^+ (ammonium) form, for this is the favoured form for uptake by waterchestnut, and is less easily leached than the NO_3^- (nitrate) form.

The crop requires very little attention after planting other than the fertiliser applications and prophylactic pest/disease control. Once corms have formed they are susceptible to damage from trampling in the field, and the canopy of the crop, (actually the stems as the plants have no true leaves) is so dense as to prevent physical entry to the field without fear of lodging and loss of photosynthetic activity. Stems should as far as possible be kept free from damage by wind, herbivores, and pests and diseases.

Farm-level yields in Australia reach >20 t/ha but maximum marketable yields (ie. > 2.5 cm corm diameter) are less than 20 t/ha. These values are similar to those reported for China, although small plot yields of up to 40 t/ha have been reported in Australia.

Photo 2. Especially constructed ponds in Victoria with maturing crop.

Key messages

- Purchase planting material of a known named variety from a reliable source.
- Ensure access to mechanical harvesting and to markets have been established before embarking on large-scale production.
- Monitor growth of plants on regular basis (3 times weekly) to ensure appropriate water level and freedom from pest/ diseases (including wild fowl and herbivores).

Pests and diseases and their control

Well-tilled land treated with general purpose herbicides (eg. Roundup) reduces the incidence of most weeds, as does the use of compact and composted mulches (eg., filter press mud) during the fallow season. If soil type dictates that ponds and bunds are linked with polyethylene sheets, then the incidence of weeds is much reduced. Aquatic species such as the giant sedge (*Cyperus exaltatus*) are well adapted to compete with waterchestnut and seed sources should be eliminated wherever possible.

Insect pests of waterchestnut are known, but with few exceptions are not devastating. Green and long-horned grasshopper and snout moth larvae bite the bases of stems and the rice water weevil (*Lissorhoptrus oryzophilus*) damages corms, as do mole crickets (*Gryllotalpa* sp.). Stem damage may be prevented by use of Lorsban 500EC but there is no easy remedy for corm damage in the field.

In 1997 outbreaks of *Nisia grandiceps* (a sucking insect) and *Scirpophaga* (a moth species) were reported, and also controlled by use of Lorsban 500 RC. A rust (*Uromyces* sp.) attacks waterchestnut, and is controlled in its early stages by sulphur dust. Stem blight present on acid soils (pH 5.5) caused by *Cylindrosporium eleocharidis* (Lentz) is chemically controlled by corm dressings or spray with Benomyl, Thiophanate and Amban, and can be controlled by rotation with non-host crops. Waterchestnut wilt, reported in China and caused by a specific race of *Fusarium oxysporum*, is not present in Australia, which reinforces the need to maintain effective quarantine protocols for the import of fresh waterchestnut materials.

Ducks are a major worry to some producers (30% of respondents in an industry survey) and netting, sound and lights are effectively used to reduce damage. Bandicoots and mice also cause damage to corms if ponds have been drained.

Harvest, handling and postharvest

Ponds must be drained for hand harvest, and for one of the four mechanical harvesters developed in Australia. The advantage of the other three harvesters is in their flexibility of use; they can operate during or after rainfall. Harvest can take place once the stems have browned off, and some producers burn off the dead stems. Corms keep well underground if frosts are not severe, as they are found at depths ranging from 7–20 cm. In-field storage can extend the harvest period, but once temperatures around the corms rise to 13°C, shoot formation occurs and the retail attractiveness of the corms is reduced.

Waterchestnuts are readily bruised during harvest, leading to saprophytic fungal and bacterial activity and at times fermentation; so they must be handled with care. Following harvest, corms are washed, cleaned, and graded by size according to market outlet. Likewise, packaging form and size also depends on market outlet, with types ranging from 200 g plastic bags to 5 kg cartons. Currently corms are not graded for sweetness, but within three years a new non-invasive near infra-red apparatus will probably provide this service to producers and their customers.

Cool storage is essential for the holding of produce in Queensland, while ambient winter temperature storage suffices in Victoria and the south of NSW for short periods. Air-dried sound corms may be stored for up to six months at 1–4°C, and surface sterilising with sodium hypochlorite reputedly extends that period. A small proportion of the harvest is saved for next year's crop, and is usually stored in this manner. To gain chain-store markets for fresh produce in Australia, it is important to have it available throughout the year—hence the interest in extending the storage life of fresh waterchestnut.

Currently no large-scale peeling of Australian produce is undertaken, although core punching of small waterchestnuts is used as a means of value-adding for the low-priced small-size category. A range of bottled produce, at the cottage industry level, is niche-marketed.

Economics of production

Costs of production were variously estimated at from $2.00/kg to $5.75/kg as a response to a recent survey among waterchestnut growers, but precise data are not available. Table 2 outlines the most probable general costs involved, expressed as those required for setting up 0.1 ha of commercial production. Economies of scale are evident particularly in the fixed costs, and hiring of facilities, especially the harvester and cold storage, will prove more attractive to the smaller- scale grower.

Research imperatives

Australian producers of waterchestnut have limited knowledge of mineral nutrition requirements, especially when using organic forms of nutrients. They also need to be able to extend the harvest season, especially bringing it forward before June, and to extend the postharvest life of fresh produce to ensure its year-round availability. There is a need to identify the genetic nature of planting material—this and the development of simple mechanical peeling are currently topics for research to help Australian producers.

Table 2. Establishment and ongoing costs of production for 0.1 ha.

Fixed costs	**$**
Pond construction	4,000–8,000
Harvester (range)	10,000–200,000
Cold storage	Market price acc. to volume
Variable costs	
Planting material (annual)	300–700[a]
Fertiliser	400–600
Labour costs production	1,000
Labour costs harvest (mechanical)	1,500–3,000
Packaging and transport	1,500
Sundries	1,500

[a] Own produced after first year, representing opportunity cost.

Key contacts

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Culinary bamboo shoots

David Midmore

Introduction

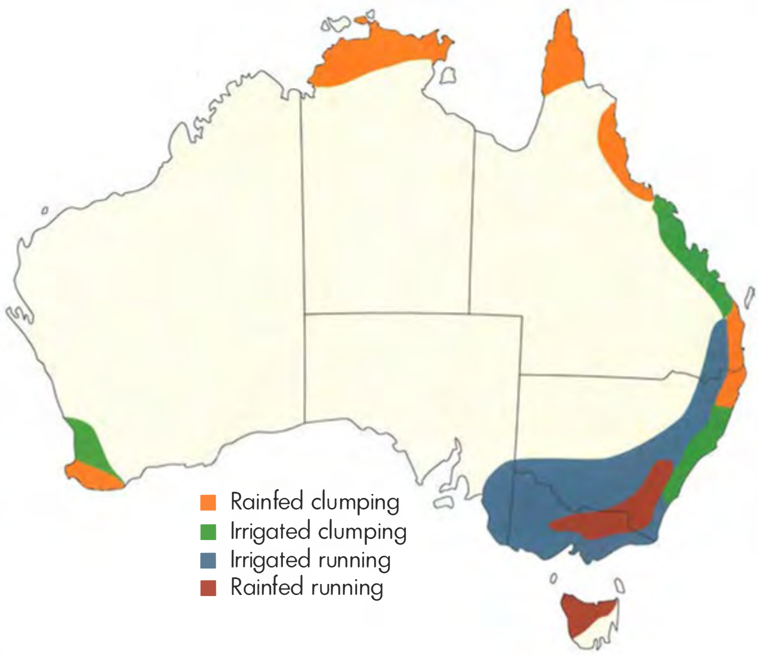
Most bamboo species will produce edible shoots. These are the young culms harvested at the time of or shortly after their appearance above the soil surface. The shoots vary in size and degree of bitterness, and most commercially-marketed shoots are derived from a small number of chosen species. Bamboo species may be conveniently split into two groups: the clumping types (Photo 1), with short rhizomes (i.e. underground stems) botanically referred to as sympodial, and the running types (Photo 2) with long rhizomes, referred to as monopodial. Very broadly speaking, the clumping types are adapted to sub-tropical and tropical climates and produce shoots after mid-summer, while the runners are adapted to cooler climates, and produce shoots in spring.

A period of from three to seven years is required between establishing a bamboo plantation and the harvesting of commercial-sized shoots, and at the time of writing, the first harvest season of plantation bamboo in Australia has just been completed. Development of an Australian bamboo-shoot industry offers opportunity to substitute fresh shoots for the estimated 6,000–12,000 t of canned produce imported annually. As with other seasonally available, perishable vegetable species (e.g. Chinese water chestnuts), bamboo is currently known to be available in the fresh form for a specific period of the year: For bamboo this period is from September until April. Postharvest semi-processing may extend the availability of near-fresh shoots to cover the harvest gap between April and September.

Bamboo shoots are important constituents of stir-fry cuisine and specialised recipes, and are produced and consumed in great quantities in China, Taiwan, Thailand, Japan and Korea. Taste and presentation vary in different countries. Bamboo shoots are also canned and exported from Taiwan, China and Thailand, and the latter two countries largely supply the world market.

Markets and marketing issues

Until 1996 the Australian market for bamboo shoots, with the minor exception of some 'natural' bamboo clumps, was catered for by imported canned and preserved shoots. A $6m import value in 1992 estimated



by Dooley was based upon 1990 ABS import statistics for canned shoots ($3–6m) and calculations of consumption in restaurants and homes (1.35 million kg at $4.50/kg net). However, 4000 t were estimated to have been imported annually in the early 1980s, a figure which, given the increase in Asian tourists and residents and the change in Australian taste, could well have doubled by today.

About the author

Professor David Midmore has been with Central Queensland University as Director of the Primary Industries Research Centre (see *Key contacts* for address) for two years. His previous research experience spans vegetable and staple crops in Asia and Latin America.

The net retail price of canned bamboo shoots ranges from $4 to $8/kg which represents the absolute minimum retail price that fresh shoots would be likely to command. Currently, farmgate prices of up to $12/kg have been achieved, but this reflects the limited supply of fresh shoots in Australia. The balance between supply and demand will most likely take the farmgate price of fresh shoots well below present levels.

In countries where bamboo shoots are traditionally eaten, they rank high in the list of vegetable production volumes (e.g. second in volume in Taiwan), and they are preferably consumed fresh. To supplement the fresh market in periods of local scarcity, Japan imports fresh shoots as well as canned shoots. The months of scarcity for fresh shoots in Japan (November to March) coincide with those of peak production in Australia, which could make Japan a steady market for 250 t shoots/month, with a monthly retail value of $3.75m. Similar months of scarcity in Taiwan also dovetail with Australia's harvest of fresh shoots. Chinese populations world-wide consume bamboo shoots, so there are in Singapore, Malaysia, Vietnam, the USA, Canada and Europe markets for canned (and in the future fresh) shoots.

Bamboo plantations do not only return a profit from shoots. Cultivation also produces timber which may be used for furniture, stakes, scaffolding (as, for example, that which supported the construction of the Hand-Over auditorium in Hong Kong in 1997) paper pulp and even disposable chop-sticks. Locally-produced bamboo poles—treated against the bamboo powder-post beetle (*Dinoderus minutus*)—are actively sought by Australian importers of bamboo poles. Some reports suggest poles may be sold for $15 to $30 each, depending on diameter and length.

Production requirements

Given the range of bamboo species and their climatic adaptation, bamboo can be cultivated in most Australian climates, provided that they get enough water. Sympodial clumping species thrive in wet sub-tropical and tropical climates, while monopodial running species are adapted to sub-tropical and cooler climates with a pronounced dry season.

Photo 1. Sizeable shoot of *Dendrocalamus asper*, before harvest in northern NSW.

Photo 2. Established plantation of *Phyllostachys heterocycla* f. *pubescens* near Brisbane showing complete canopy cover.

Nevertheless, availability of water is of overriding importance for effective shoot production. The planting of clumping species in frost-prone areas should be avoided: their foliage is 'burnt' by heavy frost and if this is severe it may not grow back.

Well drained soils, of sandy-loam to loamy-clay, are ideal for bamboo, and although it is well adapted to river bank environments bamboo does not tolerate water-logged soils with a low redox capacity and reputedly does not tolerate salty soils. In Asia bamboo is often cultivated on hillsides, which helps to retard erosion. In seasonally dry sites in Australia, reticulated irrigation permits cultivation on sloping lands.

Table 1. Bamboo species for shoot production, including data on frost tolerance, traditional sites of production and estimated yields from mature plantations.

Species	Traditional production site	Frost tolerance (°C)	Recorded yield (t/ha)
Sympodial			
Dendrocalamus latiflorus	Taiwan, S. China	-4	12–20
Dendrocalamus asper	Thailand	-3	10+
Dendrocalamus giganteus		-4	no data.
Bambusa oldhamii	Taiwan, China	-8	6–12
Gigantochloa atter		-2	n.d.
Monopodial			
Phyllostachys heterocycla f. *pubescens*	N. and C. China, Taiwan, Japan	−15	6–20
Phyllostachys praecox	C China	no data	no data

If running types are cultivated, it is important to confine their lateral spread beyond the plantation perimeter. A simple vehicular track around the plantation will not suffice to prevent rhizomes from growing beyond the planted area; soil ripping to a depth of 0.5 m may well be necessary. Clumping types are essentially non-invasive, and increase in size by lateral clump-growth only. Some clumping species may, in the case of isolated, unrestricted plants, grow to diameters exceeding 15 m if not maintained, but the norm for cultivated species is 2–3 m.

Species

More than 70 genera and 1200 species of bamboo have been described, but only a handful are grown commercially for their shoots (Table 1). Clumping types have larger shoots (up to 5 kg each) than those of running types (usually not greater than 1.5 kg each) and are harvested when shoots are above ground, in contrast to shoots of running types which are mainly below soil surface at harvest. Because of the nature of plantation growth, it is impractical to enter plantations of running types with vehicles from the second year of growth onwards. Management, especially harvesting, can become more arduous than with clumping types, but access tracks at regular (e.g. 50 m) intervals minimise this disadvantage.

The major features of the prime candidates for shoot production are as follows:

Dendrocalamus latiflorus: 280–400 clumps/ha, mature plantations giving shoots of up to 60 cm in length and weighing 3–5 kg. Very popular in Taiwan, and large quantities exported to Japan. Performing extremely well in Darwin, and tremendous growth rates at all known production sites in Australia.

Dendrocalamus asper: similar population and yields to *D. latiflorus* but maybe less frost-tolerant. Shoots can reach 30 cm in diameter weighing 4–7 kg, and mature culms 30 m in length. Large-scale production in Thailand with major canned exports to Japan.

Dendrocalamus giganteus: particularly well adapted to Bundaberg conditions. Shoots slightly smaller than abovementioned species, and favoured by Vietnamese. Not yet found in plantations.

Bambusa oldhamii: more frost-tolerant than most clumping species (together with *B. strictus*) but with small diameter shoots (ca 10 cm, Photo 3) and weight (0.5 kg) offset by its good eating quality, and smaller clumps, therefore warranting higher planting density. Slower growing in all trials in Australia than *Dendrocalamus* species.

Gigantochloa atter: also narrow diameter shoots (ca 10 cm), but quite productive and sweet. Not yet found in plantations.

Phyllostachys heterocycla f. *pubescens*: known as moso in Japan, this is the most widely cultivated species in Japan and N. China, grown mainly for its shoots. Shoots range from 7.5 to 15 cm in diameter, and can weigh on average 1.5 kg, but our experience shows that this size is unlikely until plantations are mature. This may take up to 10–12 years from seed, but less from vegetative propagation. Prolific producer of shoots, with 5–10,000/ha not uncommon.

Photo 3. Sizeable shoots of *Bambusa oldhamii* before harvest at Eumundi. Note: the soil has been removed to expose shoots.

Other species currently being harvested for shoots from isolated or 'wild' bamboo plants in Australia, and marketed, include *P. nigra*, *B. vulgaris* var. *vittata* (from Gympie), *B. balcooa* (from Eumundi) and *B. arnhemica* (from Arnhem Land).

Agronomy

Since fresh bamboo seed is not frequently available in Australia, most bamboo is propagated vegetatively. For clumping species, dividing up existing clumps into one-year-old rooted culms is very effective but gives a low multiplication rate. Cutting culms into sections of one or two nodes (i.e. into pieces of stems, at least $1^1/_2$ years old, containing one or two rings each with a bud and set of root initials) and placing them upright, horizontally or at an angle, depending on species, in warm, moist conditions in black polyethylene nursery propagation bags is another way to go. Species vary considerably in their propensity to strike, according to age of culm, position of culm and time of year for propagation. Success rate is currently low, ranging from 20 to 70%, with a high of 90% for *B. oldhamii*. The reader is referred to the author and other contacts for more detailed information on this, and on layering techniques for propagation.

Key statistics

- Australian imports 6–12,000 tonnes of canned bamboo shoots annually.
- Japan imports 130,000 tonnes of canned shoots and 3,400 tonnes of fresh shoots annually.

One-year-plus culm cuttings showing shoot activity from the bud, and root development, can be taken to the field for transplanting into 50 cm × 50 cm × 50 cm holes at the desired spacing. Transplanting is best done when it is warm. Because of the high price and lack of supply of planting material, it was recommended, when setting up a clumping plantation, to buy in a number of plants, establish them in the field and undertake one's own propagation. This is a time-consuming process: up to three years before multiplication could be achieved. Nowadays, sources of *in vitro* and vegetatively propagated planting materials are available, reducing the price of planting materials considerably and allowing immediate establishment of plantations.

For running types, rhizome cutting is effective, provided young pieces of rhizome about 50 cm in length are used. An attached young culm may or not be present. The rhizomes should be planted horizontally directly to the field in warm soil to a depth of 10 cm and kept well watered. Experience shows that autumn and especially spring are the best times to propagate running types. The transplanted rhizomes (with or without attached culm) should be spaced on a 6 m × 6 m square planting, giving a population of 280 plants/ha.

Spacing of clumping types depends on the species, with the smaller structured *B. oldhamii* on 5 m × 5 m squares (400 plants/ha) and even 4 m × 4 m, in China, *D. latiflorus* at 6 m × 6 m (280 plants/ha) and *D. asper* at 7 m × 7 m (200 plants/ha). These general guidelines will be conditioned by the level of input (water and fertiliser). Fertiliser should initially be applied around the young clump of clumping and running species, but for the latter, as they extended to cover all space between the original planting positions, fertiliser should be broadcast over all land in the plantation. Some specialised fertiliser practices (e.g. application in a trench 1.5 m beyond the perimeter of the clump) are employed overseas.

Regular light fertiliser is recommended for shallow-rooted bamboo, although twice yearly is more economical of time and is acceptable provided that one application precedes the shoot production period by one month. Our own experience shows little advantage in applying more than a total of 250 kg N: 50 kg P: 140 kg/ha split into two applications for *P. heterocycla* f. *pubescens*, although recommended fertiliser application rates are notoriously specific to soil conditions. Positive response to silicon may also be noted, for bamboo removes sizeable quantities from the soil, especially once culms are removed. A mature bamboo plantation, with annual harvests of shoots and culms (for timber) would remove very approximately 220 kg N: 31 kg P: 200 kg K/ha each year largely as timber, and this should be replenished by way of organic and inorganic nutrient sources.

Bamboo shoots comprise 90% water, and adequate water supply to plants during the shoot production is crucial for high shoot yields. Our data suggest that soil moisture tension should not drop below 20 kPa while shoots are emerging, but further research is necessary to understand bamboo's water requirements out of the shoot-production phase. Microsprinklers adjacent to young clumping types, and later minisprinkers for older clumps (two years plus) and in running plantations, are effective in spatial supply of water to bamboo. A good leaf mulch develops in running type plantations, and additional mulch is added to ensure that sprouts of running types, especially the early harvested ones, are not exposed to light. Soil or compost may be sparingly heaped up to the centre of bamboo clumps to encourage shoot growth since new buds are always higher than the point of insertion of previous years' rhizomes.

Key messages

- A plentiful supply for water (rainfall/irrigation) is essential before and during the shoot season, and plantations should not be established if this cannot be guaranteed.
- A labour-intensive crop, especially during the shoot season for harvest and culling of culms.
- Most bamboo stock in Australia is unlikely to flower in the next few decades.

Bamboo produces numerous culms, and in the early establishment years the thinnest culms should be removed, for there is apparently a positive relationship between diameter of standing culms and diameter of the next season's shoots. Indeed, from year to year the diameter of shoots increases until full canopy cover. As full canopy is achieved, weeds are smothered, but during establishment they must be kept under control by slashing. Much care is necessary not to decapitate young shoots while brush-cutting.

Approximately 1500–2000 culms are common for mature running-type plantations, leaving about 300 shoots/ha each year for new culms, and culling out the same number of oldest culms. From 6 to 10 culms are present per clump in mature clumping types, ranging in age from one to four years. One to three large shoots are left each year for new culms, with culling of the same number of old culms.

Pests and diseases

Very few pests and diseases have been recorded in bamboo in Australia. A waxy scale insect is known to grow on bamboo culms, but the influence on yield is unknown. A leaf-rolling caterpillar (*Crocidophora pustuliferalis*) also colonised various bamboo species, especially *B. oldhamii*, in young plantations at Darwin. *D. latiflorus* was less susceptible, most likely as a factor of its larger leaf size. Bamboo in Australia so far has not been colonised by the insects reported to attack it elsewhere (e.g. bamboo aphid, cutworm, mites). To date bamboo in Australia is free of the diseases (e.g., bamboo mosaic virus, sugarcane mosaic virus, rusts such as *Puccinia phyllostachydis*) known to infect it overseas.

Harvesting and marketing

Shoots are manually harvested by digging around the base of the shoot, to a depth of 15 to 60 cm for running types, and close beneath the soil surface for clumping types. The shoots are cut at the transition between soft shoot tissue and fibrous rhizome, and should be stored at temperatures close to 1°C in forced air-cooling before marketing. Special narrow sharpened spades are used for harvesting running types, as are custom-made heavy duty hoe-type knives for the clumping species. However, local variations within Asia may occur, for example sharpened hoes are used for harvest of *P. heterocycla* f. *pubescens*, a running type, in Anji County in China. Shoots are currently packed in 10 kg polystyrene boxes and marketed fresh—postharvest practices are quite rudimentary in Australia and research is lacking. Cold chains will be essential for a successful industry. In Asian wet markets, bamboo shoots are stored in water, after the outer sheath has been removed, and sold on demand for direct food preparation.

Economics of production

Table 2 details expected costs for setting up one hectare of bamboo for shoot production. Costs for planting material of clumping species may drop to one half of current price as tissue-culture derived plants enter the market. Annual labour for weeding and thinning, fertiliser application and irrigation, is high at establishment, but declines to less than one half after plantation maturity.

Small shoot harvests of most bamboo will begin two to three years after transplanting, and it is important to remove shoots, especially the small diameter ones, either for sale or as culled materials, so that the culm population does not rise excessively above that mentioned earlier.

Table 2. Set-up, ongoing costs, and returns for 1.0 ha bamboo plantation for shoot production.

Fixed costs	**$**
Land preparation	450
Planting	500
Irrigation	3500
Plant material[a]	6000–9500
Cold storage	Optional
Variable costs	**$**
Annual inputs	1800
Annual labour[b]	8000
Harvesting[c]	12 cents/kg
Returns Yields[d] (marketable) 6–12 t/ha @ $3.00/kg	$18–36,000

[a] For *D. asper* 200 plants @ $30/plant
For *P. heterocycla* f. *pubescens* 625 plants @ $15/plant
For *D. latiflorus* 270 plants @ $30/plant
[b] Declining to 50% by plantation maturity
[c] Higher costs for running species, and harvest in immature plantations.
[d] At least five to eight years for complete yields, partial yields from two to four years.

Plantations will mature from 7 to 10 years after planting, giving yields in the range mentioned in Table 1.

By the end of 1997 it is estimated, through analysis of nursery sales and through surveys, that 50 ha of bamboo will have been planted in Australia, with production (once plantations are mature) sufficient to satisfy approximately one fifth of the local market during the shoot season. Overseas markets (Table 3), especially in Taiwan and Japan, must be sourced immediately to absorb production additional to the future needs of the Australian market. Postharvest research on semi-processing will aid in extending the local availability of fresh shoots, as will agronomy and species adaptation trials aimed at hastening or delaying harvest. Air freight costs of approximately $2.50/kg to N. Asia must be taken into account when assessing the fresh market option in that region, as must import tariffs raised by some countries.

Flowering

Many bamboo species flower gregariously; that is, a clone of a species will flower uniformly across regions, and even countries, in response to an unknown stimulus. Depending upon species, this gregarious flowering may span cycles of from a few decades to more than a century. As the species flowers, all culms will produce inflorescences and then die, leaving at the worst a ghost plantation without living bamboo. Propagation of species from the seed of accessions of species known to have flowered recently will reduce the risk for short to medium term flowering, but the issue is as yet incompletely understood. Gregarious flowering is preceded by a reduction or cessation of shoot formation in the previous seasons. Where not truly gregarious, this might reflect severe drought stress. Removal of the first flowering stems, and heavy application of nitrogen fertiliser can reputedly stem flowering, but we have no experience of this practice. *P. heterocycla* f. *pubescens* reputedly has a 70-year flowering cycle, and local plants in Australia derived from seed introduced in the late 1980s will be expected to flower in the middle of the next century. *D. asper* has a similar flowering cycle, and some sources of planting material are derived from a flowering event in Thailand in the early 1990s, giving some assurance that the next bout of flowering will also not occur before 2050.

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Table 3. Estimated annual figures (t) for bamboo shoot production and consumption

Country	Domestic production		Import		Export	
	Canned	Fresh	Canned	Fresh/frozen	Canned	Fresh
Australia	0	Negligible	6–12,000	0	0	0
Japan	30,000	50,000	130,000	3,400	0	0
Taiwan	330,000[a]		0	0	40,000	1000
China	1,600,000		0	0	140,000[b]	6000
Thailand	n.d.	n.d.	0	0	70,000	n.d.
USA	0	0	n.d.	7,000[c]	0	0

[a] Estimated from 33,000 hectares of plantations.
[b] Does not include moso
[c] Includes Chinese waterchestnut

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Edamame (vegetable green soybean)

Vong Q. Nguyen

Introduction

Vegetable green soybean (*Glycine max* [L.] Merr.) is one of the most important high protein vegetable crops in Asia. The soybean has been cultivated for a long time, probably from 4,000–5,000 years in China for food and medicines. Immature green beans of soybeans have been consumed as a vegetable as long as the dry soybean has been used as a bean crop.

The cultural practices for green soybean are identical with ordinary soybean except that the green pods are harvested at the mature green stage when the pods are almost filled.

It is evident from recent studies that green soybean can be grown in New South Wales and Victoria for the January to April markets. November and December are the ideal times to grow green soybean for the highest pod yield which is comparable to the average yield of 8 t/ha in Japan. Green pods from November and December plantings could also be marketed in January, February and March, which would coincide with the most favourable period for export to Japan. However, since Japanese quarantine restrictions prohibit entry of fresh green soybean from mainland Australia, green soybean targeted for Japan must be in the processed form. Only fresh-market green soybean produced in Tasmania, is allowed to be exported to Japan.

Markets and marketing issues

International trade in green soybean focuses on supplying Japan where total demand is approximately 160,000 t per year. There are two import markets in Japan: fresh-market green soybean and frozen green soybean.

1. Imported fresh-market green soybean: Imported fresh-market green soybean mainly came from Taiwan. China, Thailand and the Philippines also supplied freshmarket green soybean to Japan but occupied a very low proportion (only 10%) of the whole import market. In 1993, Japan imported 5,617 t of fresh-market green soybean. Of this, 850 t was sent to the Tokyo markets. Monthly imported volumes and landed prices are shown in Table 2.

The landed prices varied monthly but the peak occurred in March and was ¥648/kg. However, average prices for the five-year period 1990–1994 showed that January, February and March are the best times for green soybean with February being the time for highest prices in the Tokyo market (Table 3).

Table 1. Domestic production and importation of green soybean in Japan, 1985–1995.[a]

	1990	1993	1994	1995
A. Domestic production:				
Total production (t)	102,700	81,600	84,200	N/A[b]
Mar etable (t)	68,400	52,800	55,500	51,300
B. Imports:				
1. Fresh:				
i) Quantitative (t)	2,828	5,617	4,411	4,482
ii) Value (million ¥)	996	1,402	1,093	1,025
Value (A$ million[c])	14	19	15	14
2. Frozen:				
i) Quantitative (t)	40,071	51,250	56,700	52,608
ii) Value (million ¥)	12,942	10,301	10,773	8,575
Value (A$ million[c])	171	137	143	114
3. Total imports:				
Quantitative (t)	42,899	56,867	61,111	57,090
Value (million ¥)	13,938	11,703	11,866	9,600
Value (A$ million[c])	185	156	158	128

[a] Source: Ministry of Agriculture, Forestry and Fisheries, Japan Ministry of Finance, Japan, 1995
[b] N/A: data not available.
[c] Based on 1994 exchange rate: A$ = ¥75.2

Table 2. Monthly fresh green soybean imported into the Tokyo Market 1993.

Month	Taiwan		China		Domestic	
	Volume (t)	Price (¥kg)	Volume (t)	Price (¥)	Volume (t)	Price[a] (¥)
January	4	484	–	–	–	–
February	–	–	–	–	11	1,645
March	7	648	–	–	18	2,070
April	296	378	9	407	67	1,594
May	347	312	5	292	105	2,261
June	147	254	8	104	819	1,515
July	–	–	–	–	2505	898
August	–	–	–	–	2038	892
September	–	–	–	–	832	1,098
October	–	–	–	–	233	978
November	12	276	1	282	27	1,280
December	9	341	1	412	20	1,361
Total	823	329	25	273	6,583	691

[a] Showed only the highest price which was paid for Shizuoka green soybean. Total monthly volume and prices of 1993 are shown in Table 3.
Source: Seikabutsu ryutsu nenpo : Yasai hen. Tokyo Seikabutsu joho centa, 1995 (In Japanese).
A$ = ¥75.2, 1994

2. Imported frozen green soybean: In 1993, Japan imported 51,250 t of frozen green soybean of which 75% or 38,229 t came from Taiwan and 22% or 11,088 t came from China. The remaining 3% came from Thailand (1,805 t), USA (107 t) and South Korea (21 t). Average landed prices from these sources were:

Taiwan	¥210/kg
China	¥174/kg
Thailand	¥185/kg
USA	¥196/kg
South Korea	¥190/kg

About the author

Dr Vong Nguyen is a Special Research Horticulturist with NSW Agriculture at the Gosford Horticultural Research and Advisory Station (see *Key contacts* for address). Born in Vietnam, he studied in Japan and received his PhD from the University of Tokyo, Japan in 1977. He is currently involved in research into the development of Asian vegetables for domestic consumption and export to Asian markets.

Table 3. Quantitative and wholesale prices of fresh green soybean in the Tokyo Fresh Market 1994.

	1990		1993		1994	
	Volume[a]	Price[b]	Volume	Price	Volume	Price
Jan.	9	1797	15	1238	12	1618
Feb.	10	1803	11	1645	14	1338
March	27	1628	25	1668	60	900
April	147	952	374	569	321	531
May	341	952	458	689	396	873
June	1320	721	871	949	1372	720
July	2818	536	2505	583	2496	558
August	2210	650	2038	630	1902	688
Sept.	1271	553	832	868	984	579
Oct.	206	739	233	709	189	641
Nov.	20	1002	40	925	33	835
Dec.	28	948	30	1019	36	648
Total	8407	635	7433	691	7805	644

[a] V = Volume, tonne
[b] P = Price, ¥/kg., Exchange currency 1994 A$ = ¥75.2
Source: Seika butsuryutsunempo - Yasai hen - Tokyo seikabutsu seiho centa, 1994 (In Japanese).

Most of these imports were sold to the food service section at an average landed price of ¥201/kg. (Table 5). In Japanese supermarkets, frozen green soybean imported from China is sold at ¥228/400 g (or ¥570/kg.) while the Taiwanese product generally commanded a higher price of ¥300/400 g (or ¥750/kg).

The price difference is due to poorer quality product from China. Recently, the Chinese product has improved in quality as Taiwanese companies have transferred their processing technology to China, resulting in a larger volume of frozen green soybean being shipped to Japan in 1995 (Table 5).

3. Imported seed of vegetable green soybean: There is a small market for import of seed of green soybean into Japan. Hokkaido, the major seed production area for the Japanese green soybean market, has decreased in area from 476 ha in 1987 to 422 ha in 1992, resulting in short supply of approximately 200 t of seed. In Australia, seed of green soybean would be produced in the southern coastal areas of New South Wales and on the east coast of Victoria. Pod shattering when ripening is the major problem for production in hot, dry inland areas.

Production requirements

Green soybean is a summer crop which has adapted to the warm or hot conditions of the New South Wales coastal weather. Soil temperatures greater than 15°C are needed for effective germination and seedling growth, but the most rapid rate of germination occurs at 20°C to 25°C. Plants are grown successfully on a wide range of soil types, from black self-mulching clays and red-brown earths of the inland river valleys to the light-textured sandstones

Table 4. Imports of frozen green soybean and landed prices in the period of 1984–1993, Japan.[a]

	1985	1990	1991	1992	1993	1994	1995
Total import (t)	31,044	40,071	42,621	44,063	51,249	56,700	52,608
Taiwan (t)	30,959	38,825	40,629	39,128	38,229	30,661	27,350
Landed price ¥/kg		323	237	238	201	201	163

Notes:
- Imports increase every year, and achieved more than 50,000 t in 1993.
- Main suppliers are Taiwan and China.
- Markets for frozen green soybean include the food service sector (drink bars, take-away food and supermarkets).
- Retail prices are approximately ¥650/kg.

[a] Source: • 1994 Shokuhin Seisan Yunyu Shoki. Shokuhin Ryutsu Kenkyukai (In Japanese) Tokyo, Japan
• Agro-trade Handbook 1996. Nihon Boekishinkoka (In Japanese), Tokyo, Japan.

of the New South Wales coast. Vegetable green soybean prefers well-drained soils and under irrigation they are easily managed to produce high yields. Green soybean can be harvested within 68–86 days depending on planting time.

Varieties

- **Cultivars**—Commercial cultivars should have high-yielding pods with an average of 40–50 pods per plant with pod length >4.5 cm and pod width 1.3 cm and no more than 175 pods weighing 500 g. They should also have a fresh green colour, be of large size (2.5–3.0 g fresh weight per pod), preferably with white pubescence, colourless hilum, high ratio of two to three seeds per pod and be of good eating quality. Of 22 cultivars imported from Japan, two (GSB-1 and GSB-4) have shown promise, having achieved more than 9 t/ha on the New South Wales Central Coast in the December planting. The average yield in Japan is 8 t/ha.

The planting time is from November to early January for the January to April markets. Sowing from mid-January is not recommended due to the risk of unfilled pods caused by cool weather in April. The tested cultivars which were used in this study were unsuitable in the Murrumbidgee Irrigation Area of New South Wales. Seed samples are available at the Gosford Horticultural Research and Advisory Station (Phone: (043) 481900; Fax: (043) 481910).

Agronomy

The seeds need to be inoculated with *Bradyrhizobium japonicum* strain CB1809 and are sown at planting densities of 0.15–0.20 m × 0.90 m (55,555–74,000 plants/ha) to produce a high proportion of marketable pods which contain two and three seeds each. For seed production, planting density of up to 130,000 plants/ha (0.10 m × 0.75 m) is used to increase seed yields.

Table 5. Imports of frozen green soybean in Japan and landed prices by country in 1995.

Country	Volume (t)	Value (million ×)	Landed price (×/kg)
Taiwan	27,350	4,753	173
China	21,377	3,204	150
Thailand	3,538	575	163
Vietnam	192	20	104
Indonesia	55	8	145
Canada	47	7	149
USA	22	4	182
Hong Kong	21	3	143
New Zealand	10	1	100
Total	52,608	8,575	163

Fertilisation of green soybean in early growth of plants should be focused to form good plant height and to produce maximum pod numbers. The combination of N:P:K at the rate of 78 kg. N:104 kg. P:64 kg. K per ha should be applied as a basal dressing. However, to maximise the marketable pod yield, one side dressing of potassium nitrate at the rate of 100 kg. per ha (13N:46K) would be necessary at flowering. Lack of nutrition at reproduction stage could lead to an increase in number of unfilled and/or one-seed pods.

Irrigation—Green soybean requires a large amount of water for growing, particularly at the vegetative stage, for flower bud formation and for pod development. Insufficient water during flowering to pod growth stage reduces flower numbers and causes pods to drop.

Pest and disease control

Weed control is very important for green soybean as weeds badly affect yield and pod quality. The herbicide that was successfully identified for green soybean at the Somersby Research Farm was Dacthal® (pre-emergence, 6 kg./ha).

Diseases and insects—The most common diseases and insects that were found on the Central Coast of New South Wales were Sclerotium crown rot (fungus *Sclerotium rolfsii)* and caterpillars of budworms (*Helicoverpa armigera*) and cutworms (*Agrotis* spp.). Warm and moist weather favours these diseases and insects.

Growing vegetable green soybean for Japanese domestic freshmarkets and potential export to Japan in frozen form.

Vegetable green soybean for seed production for export to Japan. The average yield of seed is approximately 1.5 t/ha.

Detached type (right) of vegetable green soybean in Tokyo Wholesale Markets, Japan. The left carton is fresh burdock.

Harvesting, packaging and postharvest handling

Harvesting—Green soybean should be harvested within 68 to 86 days after sowing, depending on cultivars and planting times, when 90% of the pods become filled and have a f.resh green colour. Green soybean can be harvested three days earlier and/ or later, but the pod yield could be lost at the rate of 0.5 t/ha/day.

Pod yield of cultivars growing on the New South Wales Central Coast achieved a high yield of 9 t/ha in the December plantings.

Mechanical harvesting—The fresh bean harvester does a very good job in harvesting green soybean, removing approximately 76% of beans and separating foliage and stalks. Harvest time, using the single row machine, is approximately a quarter hectare per hour. Approximately 7% of beans harvested by machine were bruised.

There are three types of vegetable green soybeans sold in Asian markets which are:

Attached type: (pod-bearing plant), marketed in bundle form which is the most desirable in fresh markets as Japanese customers believe this type keeps pod quality longer, ie. flavour and taste. The top leaves and small damaged pods are removed while whole plants with leaves, pods, stems and roots are packed in bundles or in 5 kg. wooden boxes or cartons.

Detached type: (pod only) is marketed in plastic net bags. Only marketable pods (two- and three-seed pods) are selected and packed in these bags.

Attached types usually obtain higher prices than the detached types because of better pod quality and these high prices meet the costs of transport.

Harvesting, de-podding and packaging are labour intensive and need to be carried out in as short a time as possible to retain the freshness of green pods.

Fresh bean: (bean only) in which beans are shelled and marketed as fresh beans.

The first two types are the most popular form in Japan while the fresh, shelled beans are most popular in the Chinese markets such as Taiwan, Hong Kong and Singapore.

Frozen green soybean, which is the major type of green soybean imported by the Japanese markets, is the detached type which is frozen by using Individual Quick Frozen (IQF) technology.

Specific processing requirements

- With IQF technology, both carbon dioxide (CO_2) and nitrogen liquids produced a highly satisfactory quality of frozen pods.
- Blanching at 95°C constant for two minutes could easily produce 'popped' frozen green soybean.
- After blanching and cooling, it is desirable that the temperature of the bean should be less than 16°C.
- Freezing immediately after blanching is recommended to avoid build up of bean temperature which would cause a high percentage of undesirably dark and bruised pods.

The Taiwanese processing flow chart is shown in Figure 1.

Attached type of vegetable green soybean in Tokyo Wholesale Market, Japan

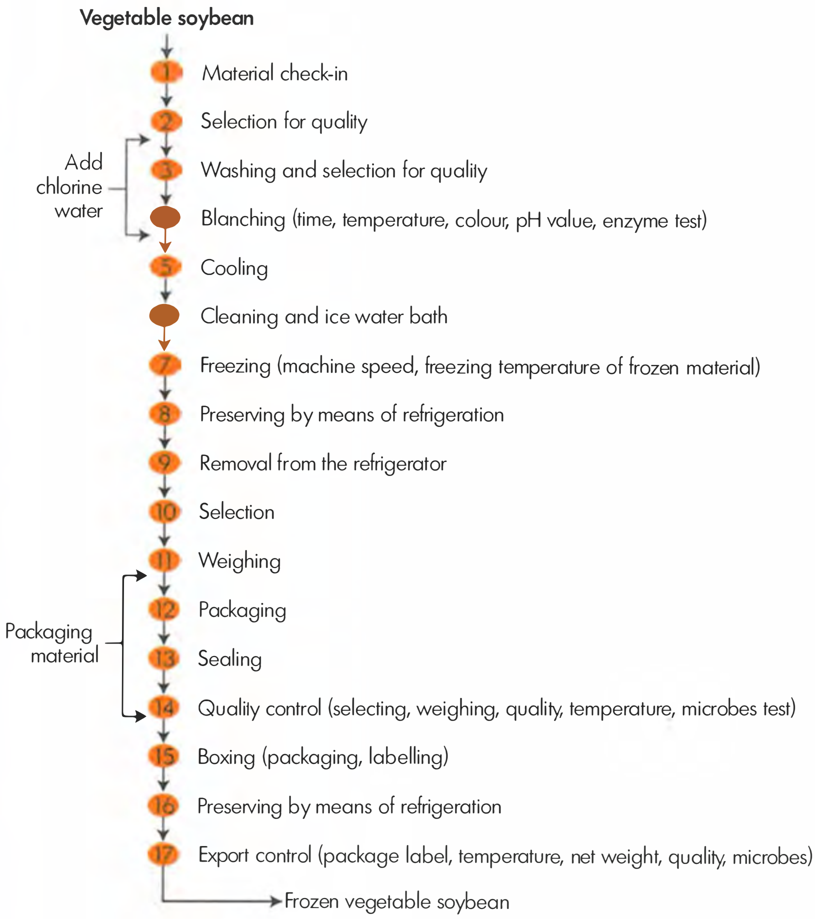

Figure 1. Frozen vegetable soybean processing chart. (Source: Liu and Chanmugasundaram, 1984)

Future outlook

Discussion with Japanese vegetable importers has confirmed the potential of fresh vegetable green soybean as a cash crop for export from Australia. However, due to quarantine problems, only green soybean grown in Tasmania is allowed to be exported to Japan as fresh product.

A previous study has shown that many tested cultivars which are high in yield and pod quality can be promoted by the Tasmanian vegetable industry, thus providing opportunities to target peak periods for demand of fresh markets in Japan during January, February and March.

For frozen green soybean, investigation of Japanese markets has shown that average wholesale prices have reduced annually since 1990 from ¥323/kg. to ¥163/kg. in 1995 (Table 4). The price reductions may be due to an increase of Chinese and SE Asian supplies. If the quality of Chinese supply improves, as mentioned above, wholesale prices could drop as low as ¥150/kg because of low labour costs in China and SE Asia. The value of Japanese Yen, which has recently decreased to ¥88/our Australian dollar (June, 1997) is an important factor for consideration. The break-even price for Australian frozen green soybean is A$1.55/kg. (Table 6).

Organic green soybeans in both fresh and frozen forms are also required by Japanese trade houses.

Table 6. Gross margin for vegetable green soybean growing on the Central Coast of New South Wales.

Enterprise: Irrigated Green Soybean Central Coast Unit: 1 Ha Income: 5,000 kg. @ $2.00/kg $10,000		
Variable costs:	**Cost per unit ($)**	**Standard budget ($)**
Two cultivations – 1 hr		25.22
One broadcast (fertiliser) – 0.3 hr		3.78
Bedforming –1 hr		12.61
Sowing:		
Seed – 45 kg/ha	5.00/kg.	225.00
Sow –1 hr/ha		12.61
Growing:		
Fertiliser – 30 bags/ha	17.33/bag	519.90
Side dressing KNO_3 – 4 bags/ha	48.60/bag	194.40
Five boomspray – 2 hr		126.10
Weedcontrol Linuron® – 8 kg/ha	34.00/kg	272.00
Spray:		
Two Ambush – 0.1 L/ha	134.00/1	26.80
Two Lannate – 2.1 L/ha	16.87/1	70.85
Dithane M – 0.15 kg/ha	4.50/kg	0.68
Benlare – 1.1 kg/ha	50.53/kg	55.58
Irrigation – 7.5 mL/ha	35.00/ml	262.50
Pumping – 7.5 mL/ha	17.00/ml	127.50
Harvesting:		
Picking, grading, washing, packaging	0.35/kg	1,750.00
Processing (snap frozen)	0.30/kg	1,500.00
Packaging materials:		
Plastic bag: 24 cm x 12 cm printed: 25,000 bags	0.0075/kg	37.50
Carton: 10 kg @ $2.00 500 cartons	0.20/kg	1,000.00
Transportation to Japan (by sea)		
$4500 for container of kg 15,000	0.30	1,500.00
Total variable costs:		**7,723.00**
Gross margin/ha:		**2,277.00**

Table 7. Parametric budget-effect of yield and price on gross margin/ha.

Yield kg./ha	**Price ($/kg.) (C and F Japan)**				
	$1.50	**$1.75**	**$2.00**	**$2.25**	**$2.50**
3,000	–908	–158	592	1,342	2,092
4,000	–566	434	1,434	2,434	3,434
5,000	–223	1,027	2,277	3,527	4,777
6,000	119	1,619	3,119	4,619	6,119
7,000	462	2,212	3,962	5,712	7,462

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Long white radish (daikon)

Vong Q. Nguyen

Introduction

Long white radish belongs to the mustard family, Brassicaceae. They have been consumed in China since 400 BC and are still one of the most important vegetables in Asia with a production of approximately 20 million t/year.

The radish plant is erect, with a short, non-branching stem supporting leafy rosettes. It has a swollen tap root with narrow, round petioles and the mid-vein is light green in colour. The radish leaf is rich in carotene (pro-vitamin A) and calcium while the root is a good source of vitamin C and some potassium and dietary fibre. The leaf, root, seed pod and sprout are consumed as a vegetable.

Long white radish, which is one of four types of radishes, is the most extensive vegetable crop grown in Asia. The other types are twenty-day radish, leafy radish and sprout radish.

Markets and marketing issues

Most of Asia would be considered as suitable markets for long white radish. Japan, for instance, produced 1.6 million t of radish in 1994, valued at ¥164 billion (equivalent to A$2.2 billion [A$ = ¥75.2]) in wholesale markets. Production of long white radish (called Daikon) in Japan was reduced from 2 million t in the 1980s to 1.6 million t in the 1990s and production now appears to be declining in most Asian countries as it is a heavy vegetable which brings low prices. However, because of the demand for processing products such as radish pickles, takuan, dried radish and frozen radish, opportunities exist for supplying fresh and processed long white radish to Asia, particularly Japan which, it is believed, imports a large amount of radish in both fresh and semi-processed forms for the pickle industry.

Long white radish imported into Japan is classified under 'Salad beetroot, salsify, celeriac, radishes and other similar edible roots (07.06.90.000)' which shows that imported quantities are less than 500 t/year during the last four years from 1990–1994. Japan also imported 5 t of fresh radish from the Philippines at ¥106 per kg. (CIF). The wholesale price of Daikon in Tokyo Wholesale Markets provides an indication of the import prices for Daikon (Table 1).

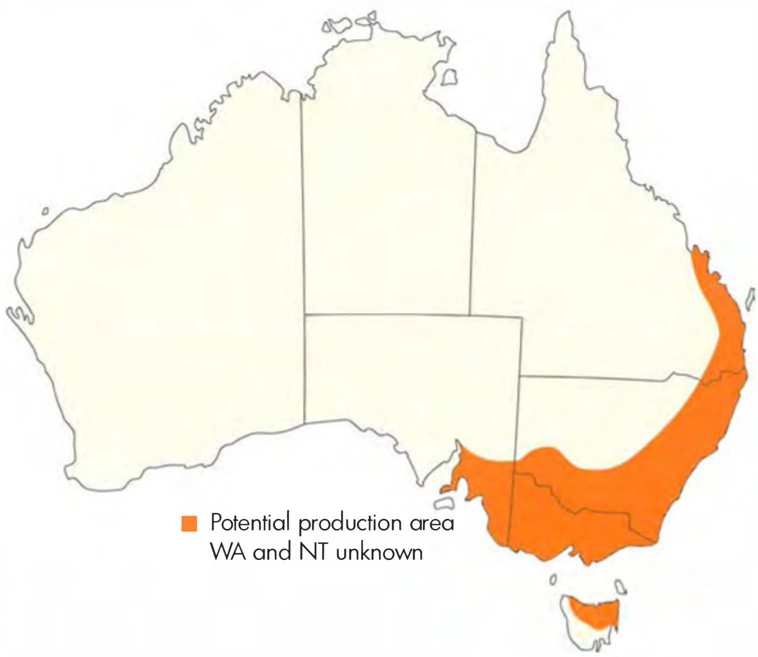

Table 1. Wholesale market throughput and price of Daikon at Tokyo Wholesale Markets 1992–1996[a]

Month	1992		1994		1996	
	Vb	Pc	V	P	V	P
Jan.	15,125	57	13,062	87	14,763	82
Feb.	15,852	83	13,732	121	17,032	77
March	15,974	71	14,596	105	16,699	79
April	13,611	105	14,672	80	13,614	130
May	12,228	95	12,017	77	13,183	86
June	10,544	155	11,555	75	10,711	88
July	13,521	77	11,870	83	11,402	120
August	12,227	97	11,967	118	12,097	101
Sept.	16,117	118	14,005	113	14,876	76
Oct.	17,381	67	14,784	139	15,175	73
Nov.	15,359	63	13,704	113	13,451	63
Dec.	18,839	56	16,448	102	17,432	67
	176,778	84	162,413	102	170,435	85

Sources:
a 1996 Tokyo Wholesale Markets Annual Report of Fresh Fruit and Vegetable Section, Tokyo Fresh Fruit and Vegetable Information Centre (In Japanese).
b V = Volume, t
c P = Price, ¥/kg.; A$ = ¥75.2 in 1994

Long white radish can be processed to give products such as pickles, dried and frozen radish.

Pickled radish comprised 32% of approximately A$6 billion of the Japanese pickle markets in the 1990s. Of these, takuan is the most popular processed form of pickled radish. The production of takuan has declined from 250,000 t in 1985 to 210,000 t in the early 1990s.

There are four types of takuan available in Japanese markets: pickling radish with rice bran (nakazuke takuan), pickling radish with miso (misozuke takuan), pickling radish with sake lees (kasuzuke takuan) and pickling radish with soy sauce (shozuzuke takuan). One form of pickling in which radish is the major ingredient, referred to as one-night quick pickling (ichiyazuke), has recently become popular in Japan.

Information in Japan on the importation of radish for takuan is unclear, e.g. in 1991 Japan produced 210,157 t of takuan but in the same year produced 1,692 t of dried radish as well as importing 30 t of fresh radish and 7,139 t of salted radish, making approximately 10,000 t of material for the production of takuan. The gap of approximately 200,000 t of takuan has raised a question mark about supply sources (Table 2).

Separate import statistics are not kept for takuan as it would be classified under 'Materials for pickles' of which Japan imported 220,413 t valued at US$171 million in 1994.

Dried radish is used for cooking, soup, nigiri rice and 'gobugobu' pickles. There are three types of dried radish available in Japanese markets, and they are fine sliced (usukiriboshi), long strip or ribboned (kiriboshi) and cross-cut (wagiriboshi). Production of dried radish in Japan has increased by more than 1,000 t in 1993 but the wholesale price has dropped to only ¥308 per kg (Table 2).

About the author

Dr Vong Nguyen is a Special Research Horticulturist with NSW Agriculture at the Gosford Horticultural Research and Advisory Station (see *Key contacts* for address). Born in Vietnam, he studied in Japan and received his PhD from the University of Tokyo, Japan in 1977. He is currently involved in research into the development of Asian vegetables for domestic consumption and export to Asian markets.

Table 2. Production of radish products and total pickle consumption in Japan, 1985– 1993.[a]

Year	Radish products				Total pickle production (t)	Dried sliced radish	
	Dried whole radish		Takuan production (t)	Radish pickle production (t)		V	P
	V[b]	P[c]					
1985	2,836	136	254,404	502,341	1,043,705	537	482
1986	3,305	103	249,913	527,076	1,060,716	450	595
1987	2,940	117	239,916	508,085	1,081,930	676	353
1988	2,205	161	219,162	410,272	1,119,891	639	421
1989	2,060	138	218,457	409,316	1,178,718	745	392
1990	1,507	193	213,371	381,738	1,180,166	512	523
1991	1,692	204	210,157	387,046	1,200,410	388	903
1992	1,717	147	N/A	N/A	N/A	413	875
1993	1,766	115	N/A	N/A	N/A	1,127	308

Sources:
a 1996 Tokyo Wholesale Markets Annual Report of Fresh Fruit and Vegetable Section, Tokyo Fresh Fruit and Vegetable Information Centre (In Japanese).
b V = Volume, t
c P = Price, ¥/kg.; A$ = ¥75.2 in 1994

Dried radish imported into Japan is classified under 'Vegetables – dried' of which 44,863 t were imported in 1994 valued at US$255 million.

Frozen radish is used mainly for Japanese traditional food 'oden' (casserole) in which the root is cross-cut at approximately 10 cm in length, blanched and frozen by Individual Quick Frozen (IQF) technology.

Frozen radish is imported into Japan under 'Other Frozen Vegetables [0710.80.090]' which includes lotus root etc. and has been dramatically increased from 85,416 t, valued at approximately US$140 million in 1994 to 99,896 t, valued at US$166 million in 1995.

Japanese daikon grown on the Central Coast of NSW. Green shoulder (neck) daikon is used for the freshmarket whilst white shoulder is used for processing.

Production requirements

Long white radish is essentially a cold-season vegetable. However, it can be grown year round in Australia.

Producing high quality radish during mid-summer and winter requires great care as high summer temperatures and strong sunlight prompt the roots to develop rapidly in size, and become pithy soon after maturity. Low temperatures slow vegetative growth, stimulate the forming flower buds and cause bolting in spring. Bolted radish is not marketable as the roots become woody and pithy. Therefore, the best time to grow long white radish is spring and early autumn.

Drying whole plants in shade with good ventilation area (left) for takuan pickle (right).

Varieties

There are several varieties of long white radish grown in Asia, the main differences between them being size, root shape and root neck colour. The main root shape grown is triangular with a white neck.

When selecting a radish variety, also check shape and colour, since market requirements vary with ethnic groups. The Chinese and Indo-Chinese require a white-necked, thin (5 cm diameter) root growing to 25 cm in length, but the Japanese fresh market prefers the green-necked, fat (7–10 cm diameter) radish grown to 30–35 cm in length.

For processing, the root shape is not as important but the flesh must be crunchy, and low in water content for faster drying. It must not be pithy. Radishes are marketed when the root mass is approximately 300–600 g, but depending on the type and market, they can be grown to even greater weights; a special Japanese variety called 'Sakurajima' (shape 5) can be grown up to 20 kg. and a variety called 'Moriguchi' (shape 8) can grow up to 120 cm long with a width of 2.5 cm (Fig. 1).

There are three other types of radish used in Asia which are:

Twenty-day radish Most commonly cultivated radish in Australia and other Western countries. There are several varieties, differing in size and shape, but they all produce relatively small roots of approximately 30–40 g and are coloured red, white or red/white. They are very fast growing, maturing in approximately 30 days in summer and 45 days in winter.

Leafy radish Grown as a leafy vegetable, this radish has large foliage and small roots. The plant is harvested when it has grown 10–15 leaves, each measuring 25 cm in length. The growing method is similar to twenty-day radish.

Sprout radish A specific variety that grows long, white stems. Seeds are sprouted in moist, dark conditions at approximately 20–25°C and grow to approximately 15 cm over ten days and are marketed after the roots are removed. The Japanese are heavy consumers of sprout radish under the name 'Kaiware daikon' with approximately 15,000–20,000 t/year consumed in 1994.

Seeds of Chinese, Japanese and Korean radish cultivars are available in most Asian supermarkets in Sydney, Melbourne and Brisbane. They are also available from Australian seed companies, particularly the Japanese cultivars.

Agronomy

A fine, well-prepared, raised bed is important for growing long white radish. Application of animal manure or compost before sowing helps build up the water-holding capacity of the soil and to balance the nutrient supply. Chemical fertiliser can be used as basal application and also as a side dressing if necessary. Long white radish tolerates slightly acid soils but optimum pH of the soil is between 6 and 7.

Depending on the cultivar, long white radish can germinate in soil temperatures as low as 5°C. The optimum growth temperature is 20–25°C. The seed is sown in rows at a depth of 5–10 cm. Dense sowing and early thinning will ensure a preferred plant population of 70,000–80,000 plants/ha. Excessive plant densities will result in small, irregular-sized and misshapen roots.

Growing times differ between varieties and seasons, being normally shorter in summer and longer in winter.

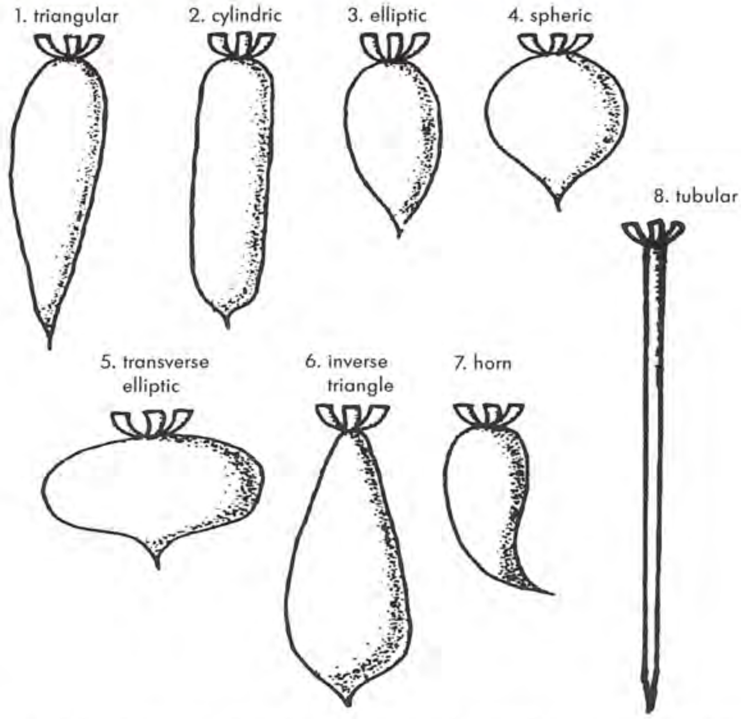

Figure 1. Root shapes of radishes. Shapes 1 and 2 are freshmarket types; the others are mainly for processing.

To produce high quality long white radish, plants must have adequate soil moisture throughout their development. Radishes are particularly sensitive to water stress, which causes pithiness in the root. Overhead sprinklers provide the moist environment required for radishes but also encourage fungal diseases, particularly in summer (not a favoured growing season).

Animal manure is normally applied in rows or broadcast. A good quality fowl manure should be applied six weeks before planting at the rate of 15 t/ha. (1.5 kg./m^{2}). Before planting, broadcast 1.5 t of chemical fertiliser G5 (N:P:K = 5:5:5) to ensure that the young seedlings have a ready supply of major elements immediately after germination. When the seedlings are established 3–4 weeks after sowing, thin them to 15–20 cm apart, side dressing with potassium nitrate after thinning if necessary. White radish needs to be grown 50–60 days in summer and 70–80 days in winter for the fresh market when the fresh root weighs approximately 0.5 kg.

Pest and disease control

Weeds are a problem for long white radish as their slow growth in the early stages makes them poor competitors with weeds. Weed control from sowing time onwards is essential, otherwise yield and quality are affected.

Pre-germinate weeds before planting the crop and control them either with knockdown herbicides or by cultivation. It is usually sufficient to hand-weed fast-maturing vegetables like white radish once during their growth.

Radishes are attacked by the same pests as other members of the Brassica family. The most serious pests found in the New South Wales radish crops are cabbage white butterfly and aphids; nematodes and black beetle sometimes cause root damage.

The most important disease is bacterial soft rot *(Edwinia carotovora)*, which is also found on other Brassica species. The bacteria are commonly found in decaying vegetable matter in the soil. They invade damaged tissue, often following other diseases. Hot, wet weather favours soft rot. A soft, mushy decay develops from the root 'neck' (near the ground) and eventually the entire root is affected by a very smelly soft rot. Soft rot can also be a postharvest problem. The disease is controlled by avoiding damage to the plant during side dressing or harvest, destroying diseased crop residues, and rotating the crop every three or four years.

Radishes are sometimes attacked by yellows *(Fusarium oxysporum)*. The fungus survives for long periods in the soil, infecting the plant through roots and growing in the water-conducting tissues. Warm weather favours the disease. Affected plants lose vigour and the lower leaves on one side of the plant turn yellow; a brown discolouring develops under the skin of the root. The disease is controlled by using resistant varieties, and rotating crops every three or four years.

Harvesting and packaging

Freshmarket radish varieties are harvested approximately eight to ten weeks after sowing. The roots are mature when they reach a 5–10 cm diameter at the 'neck'. Radishes are hand-harvested and tied in bunches of two or three roots, or sold individually. Radishes sold on the market have full foliage or are trimmed to leave 10 cm of foliage.

The root should have smooth white skin without blemishes. Internally, root flesh should be compact with no signs of pithiness or hollowness.

Radishes are susceptible to wilting. Harvesting is carried out during cool times of the day and the crop should be kept cool and moist until placed in cold storage at a temperature of 0°C and a relative humidity of 90%. The radish has a short shelf-life if pithiness develops inside the root.

Processing radishes are harvested approximately 10–12 weeks after sowing because processing cultivars need to be grown longer than freshmarket types. Roots are thoroughly washed by brush-washer machine or by hand and are prepared as per market requirements. To make takuan, all plants need to be dried for approximately 3–5 days in shaded areas with good ventilation for the roots to reduce to approximately 50% of their fresh weight. To make dried sliced radish, the leaf should be trimmed and roots are sliced and dried by either sun or in a drier until they are approximately 10% of their fresh weight. The dried radishes have a strong odour and packaging them in sealed plastic bags is desirable.

White radish is usually hand-harvested, then either tied in bunches of 2–3 roots per bundle or sold in bulk in cartons of five, 10 or 15 kg. Like other vegetables, radishes are susceptible to wilting. If possible harvest them when it is cool, preferably in the early morning, and keep the produce cool and moist until placed in cold storage.

In hot weather, pre-cool the crop to its optimum storage temperature as soon as possible after harvesting. This is best done with forced-draught air-cooling. Vacuum cooling benefits produce with a high, surface area-to-volume ratio, where rapid cooling is important, such as leafy vegetables.

Ideal storage conditions for radish are a temperature of 0°C and a relative humidity of 90–95%, but you must not freeze the produce as it can suffer extensive damage when thawing. These precautions should maintain the quality of the radish and increase its storage life.

Drying strip radish using racks and facilities—for drying table grapes

Dried strip daikon (bottom right) which will be used to make "Gobugobu" pickles (bottom left)

Table 3. Gross margin for dried, sliced radish in the MIA – gas drying

	Cost per unit ($)	Standard budget ($)
Unit: 1 ha 1997		
Income: 50 t fresh (5 t dry) less 20% loss 4 t dry.	4.50/kg	18,000.00
A. Total income		**18,000.00**
Variable costs:		
Land preparation:		
Spray × 1	20.00/ha	20.00
Roundup® —3 L/ha	10.50/L	31.50
Scarify × 1	50.00/ha	50.00
Cultivate × 2	40.00/ha	80.00
Rip × 1	50.00/ha	50.00
Pivot 900® (with above) — 120 kg/ha	480.00/t	57.60
Planting:		
Sowing	40.00/ha	40.00
Seed	276.00/kg	690.00
Growing:		
Boomspray × 4	15.00/ha	60.00
Rogor® × 4 —3 L/ha	10.00/L	30.00
Endosulfan® (with above) — 6.5 L/ha	14.10/L	91.65
Tractor	15.00/ha	15.00
Dacthal® — 24 kg/ha	32.00/kg	768.00
Cultivate	40.00/ha	40.00
Side dressing	20.00/ha	20.00
Pivot 900® (with above) — 120 kg/ha	480.00/t	57.60
Irrigation: 5.5 mL/ha	30.00/mL	165.00
Harvesting:		
Contract hand harvest — 100 bins/ha	25.00/bin	2,500.00
Bin hire — 50 t	5.00/t	250.00
Truck cartage — 50 t	10.00/t	500.00
Postharvest:		
Washing and brushing — 6 hours × 3 persons — 18 hr/ha	12.00/hr	216.00
Freight to Darling Point:	15.00/ha	15.00
Slicing: — 2 t/hour × 2 persons plus machine	50.00/hr	1,250.00
Drying:		
Drying — 357 hours	7.00/hr	2,499.00
Loading drying trays (1 min/tray) — 250 trays/t	0.06/kg	3,000.00
Unloading drying trays and packaging — 40 hours/ha	12.00/hr	480.00
Packaging: 4 t/ha	0.30/kg	1,200.00
B. Total variable costs:		**14,176.35**
Gross margin/ha: (A – B)		**3,823.65**

Precautions with pesticides

Long white radishes are eaten raw or cooked without peeling, so extreme care must be taken if using pesticides. They must be registered and approved for use and applied according to the directions on the product label. Postharvest chemical treatments are generally unnecessary.

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Loofahs, gourds, melons and snake beans

T. K. Lim

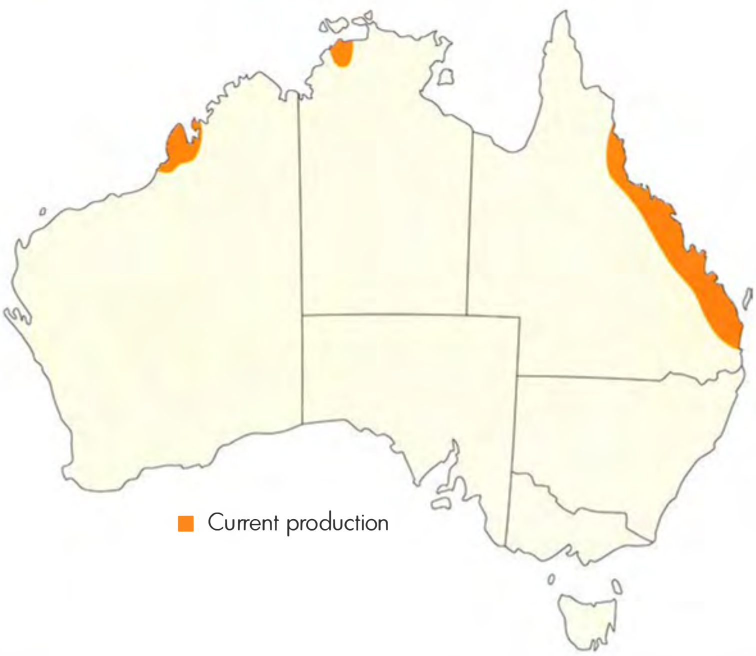
Introduction

Among the Asian vegetables that are favourably received or enjoy appreciable market demand throughout Australia are the cucurbits loofahs and gourds, and the legume snake bean. These fruit-type vegetables (Table 1) are worthy of mention among the 80 odd types of Asian vegetables grown in Australia. Besides the fruit, young tendril shoots of the bitter melon, gourds and loofahs can be eaten. The term Asian is used in the sense that they are used widely and in traditionally Asian cuisine. The types listed (except for snake gourd) are widely grown in the Northern Territory, especially from April to October. They are also grown in Queensland and the other states during the summer months of October to March, although to a lesser extent. The main feature of the Asian vegetable industry is the intensive, small sized units (mainly 2 ha blocks) which lack cohesion and coordination in production and marketing.

The scarcity of information on the production statistics of these vegetables in Asian economies reflects the relatively small-scale nature of such industries and their meagre contribution to the agricultural economy of many Asian countries. However, this does not detract from the significant role they play in the diet and livelihood of local communities, particularly in South-east and south Asia. The incomplete statistics shown in Table 2 are gleaned from various sources. Two interesting trends can be seen: a) an increasing demand for these vegetables in Asia and b) the relative importance and increasing demand for bitter gourd and snake beans over the other fruit-type vegetables.

Marketing issues

The increased Asian migrant population during the last fifteen years, particularly in Sydney, Melbourne, Brisbane and Perth, coupled with increased travel by Australians of European descent to Asian countries have helped to develop a much greater awareness of and taste for Asian cuisine. The immense profusion of recipes using Asian vegetables in cook books is linked to the diversity of ethnic groups among the Asian peoples and to differences in cultural preferences in food preparation and taste. The recent audit of the Asian vegetable industry placed the value for 1993–94 at $50.5 million; approximately 80% ($40 million) was for the domestic markets and 20% ($10 million) for the export markets. The major market channels for Asian vegetables are supermarkets,



groceries, restaurants and open markets. In Vinning's list of vegetables with high commercial significance, snake beans, bitter melons and loofah were rated higher than the gourds.

The size of the Asian vegetables industry in the Northern Territory in 1996 is listed at $3.5 million and is forecast to increase to $8 million by the year 2000. Sixty percent of this value is contributed by the vegetables listed here which have increased two-fold in value since 1995 (Table 3). The range of prices (per kg) received by growers varies according to the markets and is as follows: bitter melon $2–3.50; hairy gourd $2–3.50; wax gourd (long type) $1–2; winter melon $1.50–3; snake gourd $2–3 (local market); and snake beans $2–3.50. There are currently 42 Asian vegetable growers in the Northern Territory, from less than ten four years ago. The majority are Vietnamese, followed in descending order of magnitude by Thais, Indonesians, Filipinos, Europeans and Malaysians.

Table 1. Loofahs, gourds and snake bean grown.

Common English names	Scientific names	Vernacular names*
Bitter gourd, Bitter melon, Bitter cucumber, Balsam pear	*Momordica charantia* L. Syn *M. indica* L., *M. chinensis* Sprengel	Karella (India); Fu gwa (Cant); Ku gua (Mand); Paria (Indon); Peria (Mal); Ampalaya, Paria, Palia (Phil); Mreah (Kamp); Hiax, S'aix (Laos); Mara, Phakha, Maha (Thai); M[uw][ows]p d[aws]ng, Kh[oo]r qua (Viet)
Angled loofah (loofah), Ridged gourd	*Luffa acutangula* (L.) Roxburgh Syn. *Cucumis acutangulus* L.	Sze gwa (Cant); Oyong, gambas, petola (Indon); Ketola, Petola segi (Mal); Patola, Kabatiti, Buyo-buyo (Phil); Ronoong chrung (Kamp); Looy (Laos); Buap, Buap-liam, Manoi-liam (Thai); M[uw][ows]p kh[is]a, M[uw][ows]p t[aa][uf] (Viet)
Smooth loofah (loofah), Sponge gourd, Dish-cloth gourd	*Luffa aegyptiaca* P. Miller Syn. *Luffa cylindrica* (L.) M.J. Roemer	Shui gwa , Pu tong sze gwa (Cant); Blustru, Emes, Petulo panjang (Indon); Ketola manis, Petola buntal (Mal); Patola, Kabatiti, Kabawang (Phil); Ronoong muul (Kamp); Bwap khom (Laos); Buap-hom, buap klom (Thai); M[uw][ows]p h[uw][ow]ng (Viet)
Winter melon/gourd, Chinese wax gourd, Ash gourd/pumpkin, White gourd, Chinese preserving melon	*Benincasa hispida* (Thunberg ex Murray) Cogniaux cv. group Unridged winter melon Syn. *Cucurbita hispida* Thunbeg ex Murray, *Benincasa cerifera* Savi	Tung gwa (Cant); Kundur, Bligo, Kundo (Indon); Kundur (Mal); Kondol, Tibiayon, Rodal (Phil); Tralaach (Kamp); Tonx (Laos); Fak, Faeng, Mafaeng (Thai); B[is] dao, b[is] xanh (Viet)
Hairy melon/gourd, Fuzzy gourd, Hairy cucumber	*Benincasa hispida* (Thunberg ex Murray) Cogniaux cv. group Fuzzy Gourd	Mo gwa, Chit gwa (Cant), Jie gua (Mand)
Long wax gourd, White gourd, "New Guinea bean"	*Benincasa hispida* (Thunberg ex Murray) Cogniaux cv. group Wax Gourd Syn. *Cucurbita hispida* Thunbeg ex Murray, *Benincasa cerifera* Savi	Kundur, Bligo, Kundo (Indon); Kundur (Mal); Kondol, Tibiayon, Rodal (Phil); Tralaach (Kamp); Tonx (Laos); Fak, Faeng, Mafaeng (Thai); B[is] dao, B[is] xanh (Viet)
Snake gourd	*Trichosanthes cucumerina* L. (Syn. *T. anguina* L.)	Paria belut, Paria ular (Indon); Ketola ular, Petola ular (Mal); Pakupis, Tabubok (Phil); Ngoo ngeewz (Laos); Busp ngu, Nom pichit (Thai); D[aay] na t[aa]y, D[uw]aa n[si]i (Viet)
Snake bean, Long bean, Yard- long bean, Asparagus bean	*Vigna unguiculata* (L.) Walp. cv. group Sesquipedalis Syn. *Vigna sesquipedalis* (L.) Fruhw., *V. unguiculata* (L.) Walp. ssp. *sesquipedalis* (L.) Verdc.	Kacang panjang, Kacang usus, Kacang bulut (Indon) (Mal); itao, Hamtak, Utong (Phil); Sandaek troeung (Kamp); Tua fak yaow (Thai); D[aaj]u gi[ar]i [as]o (Viet)

*India = Indian, Indon = Indonesian, Cant = Cantonese, Mand = Mandarin, Mal = Malaysian, Phil = Philippines, Thai = Thailand, Viet = Vietnam, Kamp. = Kampuchea

Table 2. Global production of selected loofahs, gourds and snake bean.

		Bitter gourd/melon	Wax/Fuzzy gourd	Bottle gourd	Snake gourd	Winter melon/gourd	Loofah	Snake bean
Taiwan	Production (t)	21000 (1984) -35000 (1993)				25000 (1979) -26000 (1993)		
Malaysia	Production (t)	5000 (1985) -19000 (1990)						49052 (1986) 79000 (1990)
	Area (ha)	376 (1986) 830 (1994)	276 (1994)	81 (1994)	19 (1994)		527 (1986) 1181 (1994)	1640 (1986) 5170 (1994)
Thailand	Production (t)	17749 (1994)						75000 (1988) -132000 (1994)
	Area (ha)	2250 (1987)				5790 (1987)	5080 (1987)	15,720 (1987)
Indonesia	Production (t)							270000 (1985) 368410 (1989)
	Area (ha)							251905 (1989)
Philippines	Production (t)	1650 (1985) -18000 (1992)		21070 (1987)			8055 (1987)	
Sri Lanka	Production (t)	19266 (1987)			259969 (1987)			
	Area (ha)	3541 (1987)			3046 (1987)			

The following strengths and weaknesses could apply to the whole Asian vegetables industry and not merely to loofahs, gourds and snake beans. The strengths include:

- good spread of growing season in different areas
- consistent seasonal supply from growing regions
- counter-seasonal to northern hemisphere Asian markets
- good domestic market demand
- good opportunities for import substitution and export to Asian markets
- Northern Territory's proximity to Asian markets
- clean green image
- industry levy for research and development and the weaknesses include:
- fragmented, small, intensive farm units
- lack of cohesion and coordination in production and marketing

- long distance transport from northern production areas
- lack of efficient cool chain
- under-capitalised farm operations
- continuous ravages from pests and diseases
- poor understanding of English by many growers
- short shelf-life of produce
- continuous intensive production decreases sustainability
- lack of research and development funding in appropriate regions of production.

Production requirements

Wax gourds/melons are drought tolerant and are very suitable for the dry tropics like Darwin. They grow well at 24°C to 32°C. The ratio of female to male flowers has been reported to increase with relatively cool weather and shorter days such as are found in Darwin during the Dry from May to August. Snake gourd is suitable for the lowland humid tropics but cannot withstand dry soil. Its optimum temperature range is 30–35°C with a minimum of 20°C.

Loofahs are frost-sensitive and are more suitable for the lowland humid tropics. They prefer sandy loamy soils with a pH 6.5–7.5, rich in organic matter with good drainage. Heavy rain during flowering and fruiting is harmful. In this respect, areas around Darwin with generally eight months of dry weather are admirably suitable for the loofahs. Also, excessive nitrogen fertilisers can reduce female flower numbers.

Bitter melons thrive on well-drained, sandy loam soils rich in organic matter. They do not like water-logged areas, are tolerant of a wide range of environment and will grow at up to 1000 m altitude.

Snake beans prefer a day temperature of 25–35°C and a night temperature not below 15°C. They prefer soil with pH 5.5–7.5, and can grow on sandy soil if given good irrigation as they need plenty of water.

Table 3. Production of loofah, gourds and snake bean in the Northern Territory in 1995 and 1996.

Vegetable	1995 production		1996 production	
	Quantity (kg)	Value $	Quantity (kg)	Value $
Snake beans	174,800	403,080	124,680	483,696
Bitter melon	189,210	389,022	336,703	981,114
Loofah	550,50	111,200	69,294	170,936
Gourd (B. hispida long)	48,760	106,770	157,022	220,897
Wax melons			5,860	14,650
Winter melons	37,500	67,630	32,202	80,505
Total	505,320	1,077,702	725,761	1,951,798

About the author

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Varieties

The fruit of the snake gourd is often slightly twisted, cylindrical, 40–170 cm long and 4–10 cm in diameter, greenish-white and in some varieties light green with longitudinal dark green stripes. Winter melon/gourd fruit is round to oval to box shaped, green with a whitish waxy bloom. Hairy melon has cylindrical, green fruits, 20– 25 cm long by 5–8 cm and covered with fine hairs. Wax gourds have long, medium long or short, cylindrical, light green glabrous fruit often covered with a fine waxy bloom. The long slightly club-shaped variety is more popular among growers. Angled loofah is long, 20–50 cm by 5–8 cm, dull green, angled and 10-ribbed. Smooth loofah is sub-cylindrical, 30–60 cm long, smooth and not ribbed, lighter green and may have mild mottling depending on variety. Bitter melon fruit is characterised by its warty, elongate, cylindrical, 11–30 cm by 4–8 cm, light green fruit. Varieties of bitter melon consist of short, medium and long varieties or white, green and whitish-green ones. Snake bean has a long pendant, flexuous pod, 50–100 cm long by 2–3 cm diameter, with 10–25 reddish brown seeds. Varieties are many but fall into white, light-green and green types.

Growers obtain their seeds from vegetable wholesalers in Melbourne and Sydney. Most are not aware of the cultivar identity although they are aware of the existence of varieties in the market.

Smooth loofah

Bitter melon

Key message

Clean, green and nutritious

Agronomy

Planting can be done by direct seeding or by transplanting of seedlings established in small containers containing equal portions of peatmoss and vermiculite or perlite. The loofahs, wax and hairy gourds can be planted on flat land but it is advisable to plant snake gourds, snake beans, and bitter melon on raised beds or ridges. Except for winter-melon which spreads prostrate on wide, raised, plastic-mulched or bare beds, all the rest are climbing vines and require trellising. Fence trellises are recommended for snake beans and bitter melons while overhead trellises around 2 m high are recommended for the loofahs and gourds. All the climbers have to be trained up vertical supports.

Planting distances employed by growers are as follows:

- loofahs—40–60 cm by 1.5–2 m between rows
- wax, winter and hairy gourds 60–80 cm by 1.5 m between rows
- bitter melons 50 cm, 1 m between rows
- snake gourd 60 cm, 1.5 m between rows
- snake bean single row on ridges or on raised 1.2–1.5 m wide beds with double rows planted 60–90 cm between rows and 40 cm between plants.

Hairy gourd

All plants need daily irrigation during the Dry, at least 5–8 mm per day using microjet sprinklers. To induce straighter fruit growth in snake gourd, a small weight can be tied to the end of the fruit during its developmental stage.

On acidic soils with pH 5–6, as found around Darwin, it is recommended that the soil be limed with 200–300 g/m^2 2–3 weeks before planting. This should be followed by a basal dressing of a high analysis, NPK fertiliser (N = 10–16: P = 10–16, K = 10–16) and single superphosphate. Both have to be applied at the rate of 70 g/m^2 worked into the rows a week before planting. The NPK fertiliser is also applied every two weeks at 40–50 g/plant throughout the season. Additionally 2–4 kg of well-rotted, organic manure or compost should be split-applied several times during the growing period. Foliar fertilisers can be sprayed onto the plants 3–4 times during the growing season to rectify and ensure adequate supply of micronutrients: for example, sodium molybdate 1 g/L, zinc sulphate 2 g/L, iron sulphate 2 g/L mixed with low biuret urea at 5 g/L and 1 mL/L of a wetting agent. Boron should be foliar applied separately as Solubor—1 g/L before flowering and fruiting, or soil drenched around the plant at 2–4 g/L.

Pest and diseases

The most important pests of the cucurbits listed are the leaf feeding beetles, *Aulacophora* spp., mites, cucumber moth (*Diaphania indica*), *Helicoverpa* (*Heliothis*) spp., aphids, thrips, cutworms, false wire worms, and *Meliodogyne* root knot nematodes. The nematodes are a problem on the heavier soils. Diseases commonly attacking the cucurbits are powdery mildew (*Erysiphe cichoracearum*, *Sphaerotheca fuliginea*), downy mildew (*Pseudoperonospora cubensis*) and anthracnose (*Colletothricum lagenarium*).

The most important pests that attack snake beans are: thrips (*Thrips palmi*), bean fly, caterpillars, crickets, mites, root knot nematodes and parrots. The important diseases of beans are leaf rust (*Uromyces phaseoli*) and fruit anthracnose.

The best way to control pest and diseases is to use integrated pest management (IPM). In IPM, all available methods, cultural, physical, biological and chemical, are employed together in a sound compatible way to manage the pest population. IPM will result in reduced chemical use by promoting a more judicious and safer way of applying chemicals. For instance by using 'softer' chemicals like potassium soaps, light summer oils, or pheromones. Another example is to use off-season sorghum crops as green manure coupled with crop rotation to manage the root-knot nematode problem. Also for all vegetable crops it is essential that growers observe the safe withholding periods for the chemicals.

Harvesting and storage

Wax gourds and hairy melons are picked while immature, 3–4 weeks after fruit set. They keep for 3 weeks at 12–15°C. Winter melons are harvested at a more mature stage, 90–100 days after planting, and can keep for up to 6 months below 12°C.

The loofahs are harvested at the half-mature stage, 9–13 weeks after planting, as the mature stage is too fibrous. The fruits can be stored for 3 weeks at 12–15°C.

Snake gourds are picked 3–4 weeks after fruit set when they are green, tender, immature and 30–70 cm long. They store well for 2–3 weeks at 15–18°C under high humidity.

Bitter melons are harvested 3–4 weeks after fruit set when they reach marketable age, light-green, thick and juicy, 11–30 cm by 4–7 cm in diameter and not at the ripe mature, yellow-orange stage. They keep only for 2–3 days at ambient temperature but at 5°C they store for 3 weeks.

Snake beans are harvested while immature, 6–8 weeks after planting. They store well at 8–10°C for 4 weeks. Harvesting is carried out 2–3 times a week during the 6–8 weeks season.

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Snake bean

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Wasabi

Melanie Barber
Michele Buntain

Introduction

Wasabi (*Wasabia japonica* Matsum) is a perennial herb belonging to the same family of plants as broccoli, cabbage and mustards, the Brassicaceae. In its natural environment in Japan it grows alongside mountain streams. Superficially, the plant resembles a Brussels sprout stem without the Brussels sprouts. It is evergreen and forms large clumps if left undisturbed. Wasabi can be grown in raised gravel-beds above fast-flowing streams or in soil in a similar manner to other brassicas. A major limiting factor is its need for shade which raises production costs substantially.

Used with traditional Asian foods such as sushi and soba noodles, wasabi is in short supply in Japan because the younger generation is losing interest in continuing family farming traditions, farming space is diminishing under urban encroachment and problems are arising from pollution.

The major draw-card for Australian wasabi production is our ability to supply in the off-season market in South-East Asia. There is also a large domestic market for processed and, in particular, fresh wasabi for the restaurant trade.

So far wasabi has been grown in trial plots in areas in Tasmania suited to vegetable production. It is believed that parts of Victoria and some parts of highland New South Wales will also be suitable.

Markets and marketing issues

Japan is seen as the principal potential market for Tasmanian production, with the possibility of smaller markets in Korea and Taiwan. Current Japanese production is around 5000 tonnes (fresh weight) per annum. Additional opportunities also exist for import replacement in the Australian domestic market. There is a strong demand for high-quality, fresh produce by the Japanese catering and food industry. Fresh roots fetch up to $AUD100/kg on the domestic Japanese market during the colder months. This demand currently cannot be met because of the progressive contraction of traditional production sites as a result of pollution and urbanisation. While there is a high demand for fresh quality stems, a major market also exists for processed product in the form of pastes, purees and powder.

About the authors

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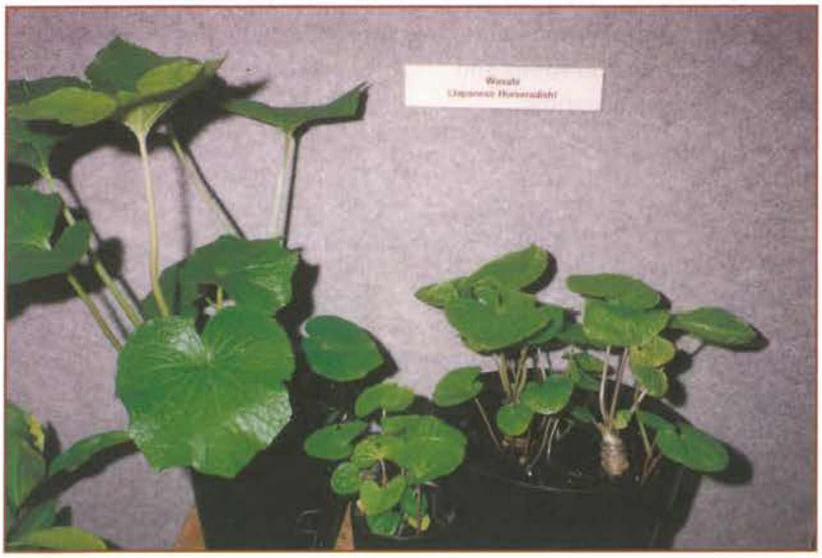
Michele Buntain (BAgSc) is an agronomist with the DPIF and has contributed extensively to new crop development in Tasmania. Her achievements include involvement with the essential oils and medicinal herbs industries.



Wasabi, Japanese horseradish

Production requirements

Wasabi grows naturally under heavy shade provided by overhanging bushes on the edge of mountain streams. In Japan, shading of commercially grown wasabi varies from no shade at all to 80% block-out of incident light. Currently the level of shading used in Tasmanian trials has averaged between 65% for soil-grown and 80% for aquatic wasabi. The shade-cloth used has been 70% black although work is under way to test other weights and colours and the consequent effects on the plants. If the plant is exposed to too much radiation, the leaves will be scorched and/or the plant will exhibit physiological wilting.

Soil culture. Wasabi grows best on soils with an open friable structure and good drainage is essential. The preferred soil types are:

- deep alluvial loam, sandy loam or sandy clay loam;
- red soils such as Krasnozems or similar basalt derived red soils which drain freely;
- sandy soils which are high in organic matter (but which as yet have not been used for trial work).

Plants from this type of production system are commonly used for processing, although New Zealand has successfully produced fresh-quality product from soil culture. Being a Brassica, wasabi is susceptible to many of the bacterial diseases and some pests known to affect most other brassicas. Extreme air temperatures and soil conditions are the major limitations to wasabi production and may determine a plant's susceptibility to pest and disease attack.

Aquatic culture. Wasabi is produced in large quantities in Japan in aquatic production systems. The stems produced in this manner fetch the highest returns for the fresh market and are reportedly larger and of much higher quality. Important variables in aquatic production include temperature, clarity, oxygen saturation and nutrient status of the water. The water temperature range of 2.3 to 19.5°C experienced in Tasmanian trials may have been too variable. The recommended temperatures are between 12° and 15°C.

Varieties

Current trials have used Daruma, Daruma Improved (from New Zealand) and Tainon No.1 (from Taiwan) cultivars. Indications have been that Daruma and Daruma Improved will be suitable for Australian conditions. There is very little material available at this stage in Australia for commercial use. It is hoped that several new varieties will be available in late 1997 for further assessment.

Agronomy

Wasabi is easily stressed and the best times to plant are most likely autumn and spring when temperatures are moderate. Autumn is preferred as it naturally follows on from seedling production. The transport of larger plants can damage leaves and stems and sometimes break them off completely. This is another reason for planting out in autumn when the plants are considerably smaller.

Key statistics

- Annual Japanese Production is 5000 t
- 50% is water grown and 50% is soil grown
- Prices peak in the colder months and can reach $AU 100/kg for fresh stems
- Key market is Japan

Soil culture. Once a site has been chosen it needs to be cleared of weeds entirely and shade needs to be constructed, taking into account any machinery that may need to be used within the shade structure such as tractors or irrigators. The shade-cloth has an important function in cooling the plants, which prefer to be between 12° and 20°C but can handle quite bright light. This means that the shade structure design should allow good air-flow for cooling. Leaving the lower section open up to around half a metre would help to provide additional ventilation and cooling. Ideally the shade structure for soil grown wasabi should be simple for easy relocation. This will allow for crop rotation and prevention of disease build-up.

Planting wasabi in stream beds

Aquatic culture. Beds need to be constructed from medium-grade gravel and raised to approximately 20-30cm in height and parallel with the direction of water flow. Plants should be planted down each side of the beds to allow roots to reach down into the wettest zone of the gravel but to prevent the stem from being submerged. Shade structures should be constructed as for soil culture. Wasabi will not grow in stagnant water or water of low oxygenation; therefore a year-round water supply of constant flow and temperature is necessary for an aquatic site.

There is little information on the specific nutrient requirements of wasabi. In Japan, soil-grown wasabi is fertilised with compost such as rape-seed cake and liquid manure. No nitrogen is applied to the young seedlings when first planted in the soil. For water-grown wasabi, a slow-release fertiliser composed of 12:12:12 (N:P:K) is applied monthly to the headwaters at a rate of 1 t/ha. Also, sulphur sprays are often applied to correct deficiency and to enhance flavour.

High-quality wasabi should grow at an even rate. This means that a number of small applications of nitrogen over the growing season should be applied. The amount applied will depend on the history of the site and its organic nitrogen levels. Phosphate fertiliser should be incorporated into the soil before planting, using a banding method of application. Once again a soil test will indicate the amounts needed. Regular leaf analysis and monitoring of nutrients will also help in fertiliser application.

Brassica crops are particularly sensitive to boron and molybdenum deficiency. It is likely that wasabi also needs these elements although nothing has been reported in the literature. In the first season before tissue-testing takes place, boron should be applied, for example, as borax at 20 kg/ha when broadcast and 10 kg/ha when placed in a band. Molybdenum can be supplied as sodium molybdate at 1 kg/ha or as a foliar application of sodium molybdate at 5 L/ha.

Irrigation of wasabi has two important functions:

- to maintain soil moisture levels
- to assist cooling of the plants.

Wasabi likes its roots to be kept moist but not to saturation point as this significantly reduces the amount of oxygen available to the plant and thereby restricts its function and growth. Tensiometers are very useful for this purpose, but the most important rule is to remember that little and often is better than one large dose.

Pest and disease control

Prevention, identification and management of disease is extremely important (a review of wasabi pests and diseases is given in Chadwick). Wasabi is susceptible to a range of bacteria, fungus and viruses. Important features to watch for include leaf spots, blackening, yellowing of leaf or petiole veins, physical damage, wilting or drooping, mushrooms in soil, mould on stems or leaves. Bacteria which infect wasabi include Erwinia and Pseudomonas; Fungi include *Phoma* sp., *Sclerotinia* sp., *Peronospora* sp., *Albugo* sp. and *Alternaria* sp.

Pests of wasabi cause damage in many ways. Feeding removes valuable leaves and stems, physical damage promotes disease and reduces stem quality and aphids can transmit viruses. Symptoms to look for include; holes in leaves and grubs, aphids on underside of leaves, leaf puckering, slugs and snails at ground level under decaying leaves or clods, grubs in the growing point of plants and leaf silvering or skeletonizing. So far, various means of chemical control have been used against the two main problems found in wasabi which are aphids and white rust. Identification of more environmentally sound means of control will continue.

Fields of wasabi under 70% shade

Harvest, handling and postharvest treatments

The whole plant is harvested or the plant is cut just below soil level with some roots intact. The stem usually reaches a marketable size of 8 to 15 cm long and 50 g or more by 18 to 24 months after planting. The price traditionally peaks during our summer months of January and February, which coincides well with anticipated harvest time. However, this may vary from year to year. The wasabi will tend to develop large side-shoots in autumn so it is best to harvest before these enlarge.

Key messages

- Supply for SE Asian off-season market
- High value, low input crop
- High initial capital investment
- Requires shade and cool temperatures
- Similarity to other crucifer cropping methods

Presentation. Colour: generally the Japanese wasabi is dark green. Wasabi that is either lighter (yellow-green) or darker (brown-green) is considered inferior though still marketable. One of the most important aspects of colour is that the inside of the stem should be pale green to ensure a good coloured paste when the stem is ground.

Shape: wasabi should have an evenly tapered stem. Uneven taper shows that the wasabi has been grown under varying environmental conditions and will not fetch the best prices on the fresh market.

Trimming: trimming is a critical part of wasabi stem presentation. Excessive trimming shows that the stem was soil-grown or there was disease present, while insufficient trimming suggests they are not getting value for money (i.e. by including lower-value petioles or roots). High-value wasabi stems have the roots removed but the base of the stem is left intact. Wasabi imported into Japan with the base removed indicates that the plant has been grown in the soil and the stem removed for quarantine purposes. Petiole trimming is also important. Trimmed too long and the market will consider you have 'weighted' the consignment with excessive low-value petiole. Trimmed too short and the perception will be that you have removed disease or the stems have been stored excessively long. Generally, petioles should be trimmed evenly to a length approximately one third the length of the stem, though this can vary between markets.

Weight: generally stems over 50g are preferred for the fresh market.

The storage of wasabi is still being investigated, although initial indications are that the best method is wrapping in a damp towel and placing in a refrigerated store. This will keep the stems fresh for several days.

Economics of production and processing

Soil culture. A model was developed to examine the feasibility of establishing a wasabi enterprise. The standard soil-culture model for comparative purposes assumed that the yield of stem material was 8t/ha, and that all the product was sold for $8/kg and later processed. No product was sold at the premium fresh-material price. In addition 2t/ha of stems was sold at $2/kg.

The net income for the enterprise was $68,000 per ha. Once established, the projected margin before overheads is $53,310/ha and based on a 1 ha development the net cash flow is $26,810 after allowing annual overheads of $26,500.

Given the above prices and returns, the profitability of the 1 ha soil culture enterprise is 11%. This return is substantially lower than the 15% level commonly accepted as the value

Wasabi stems of same age, showing variation in maturity of return required for new agricultural enterprises. However, a small increase in area has a dramatic effect on the return on capital achieved; for example a 1.25ha unit has a 19% return on investment. It is quite likely that a slightly larger soil culture system would not require significantly more input, especially of labour and land. The capital outlay for a 1ha soil culture development is $155,000.

The viability of soil-culture wasabi production is dependent on achieving a yield exceeding 8t/ha of stem material that is sold for processing at a minimum price of $9/kg.

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Key references

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Bushfoods

Bushfoods

Caroline Graham

Denise Hart

Introduction

The commercial bushfood industry has been steadily expanding since being introduced into restaurant menus in the mid-1980s. The industry currently comprises:

- wild harvesters;
- nursery operators;
- commercial producers of raw produce;
- food processors;
- hospitality providers;
- retailers;
- food service operators; and
- tourism operators.

The industry operates within a variety of commercial structures including single-purpose enterprises, networks, vertically-integrated operations and wholesale/merchandising enterprises.

Although commercial, horticultural cultivation of various bushfood species is expanding, wild harvesting is the dominant source of raw produce.

The farm-gate equivalent gross value of the industry was estimated to be $10–12 million in 1995-96. Average returns to individual businesses are reputedly low, particularly at the farm-gate level, with bushfoods being often only a small part of the business. At present the industry is poorly developed, businesses are generally under-capitalised and they, as well as new entrants to the industry, will require considerable entrepreneurial skill.

The necessary steps towards sustainable and prosperous growth in the industry include:

- establishing a market focus;
- better communication networks and dissemination of information;
- establishing recognised food-safety standards;
- setting up sustainable and profitable production systems;
- improving education and training in all industry sectors; and
- improving raw produce through genotype selection.

At this stage of the industry's development, the most commercially acceptable foods are:

- bush tomato
- Davidson's plum;
- lemon aspen;
- lemon myrtle;

Australian bushfood selection

- mountain pepper;
- muntries/munthari;
- riberries;
- quandong;
- warrigal greens; and
- wattleseed.

The majority of produce is dried, frozen or further processed into value-added products, the main markets being gourmet retail and food service. Only a small amount of fresh produce is used by restaurants. The larger food processors currently sell little produce to the mainstream retail and wholesale food markets. However this market would increase by:

- providing produce in an acceptable form and at a competitive price;
- offering it in guaranteed quantities; and
- meeting minimum quality standards.

Markets and marketing issues

Australian native bushfoods are generally sold as raw produce to the buyers listed below.

- value-adding native food processors;
- gourmet food processors and manufacturers;
- cottage-industry processors: and
- restaurants and caterers which use local native foods.

The following tables outline indicative pricing levels for wholesale produce and for the variety of manufactured v-a products. These prices cover an average range as listed by current processors and do not reflect seasonal fluctuations.

Value added products are sold to:

- specialty food stores and delicatessens;
- distributors which service the hospitality, food and catering industry;

Raw produce and annual tonnages traded.

Species	Type	Wholesale price/kg (approximate)	Total product used by processors. 1995–96 (t)[a]
Bush tomatoes	Whole, dried	$55–$60	5.0
Illawarra plum	Fresh, frozen	$27–$30	2.5
Kakadu plum	Fresh, frozen	$26–$30	2.5
Lemon aspen	Fresh, frozen	$28–$30	3.6
Lemon myrtle	Dried, ground	$90–$120	2.5
Lemon myrtle	Whole leaf, dried	$100–$110	2.5
Muntries/Munthari	Fresh, frozen	$24–$26	5
Native herbs	Aniseed, dried	$3–$6 per 25g	0.04
Native herbs	Mint, dried	$3–$8 per 25g	
Native herbs	Thyme, dried	$5–$8 per 25g	
Native mountain pepper	Dried leaf and berry	$110	2.5
Quandong	2nd grade dried halved	$90–$110	5.0
Riberry	Fresh, frozen	$30–$35	2.5
Warrigal greens	Fresh	$2.50–$16	0.22
Wattleseed	Clean, roasted	$30–$35	6.0
Wattleseed	Clean, roasted, ground	$53–$59	
Wild lime	Fresh, frozen	$28–$30	0.71
Wild rosella	Fresh, frozen	$28–$30	3.0

[a] Information on tonnage used reflects current demand from bushfood processors and is provided by processors and wild harvesters.

- major department stores, airport stores and other tourist speciality outlets;
- supermarket gourmet food sections; and
- specialty food services to airlines and tourist resorts.

The following information outlines some indicative wholesale prices. It does not comment on the consistency or quality of any individual product.

Market demand

Reliable information on market demand is difficult to obtain. The table on the following page shows how many plants are needed to fill known current demand, based on actual tonnage traded in 1995/96. Tonnage traded refers exclusively to current bushfood processors and does not consider the potential requirements of mainstream food manufacturers.

According to mainstream food manufacturers, the following products have potential if they are available in sufficient quantity, an acceptable form, and at the right price.

- native mountain pepper in a dried/ground form;
- native herbs such as wild thyme, native aniseed and mint;
- riberry without the seed in a dried/ground, essence, flavour, puree form;
- Illawarra, Davidson, Kakadu plum in essence, flavour and puree form;
- lemon myrtle in a dried/ground form;
- rosella in essence, flavour, puree form; and
- quandong in essence, flavour, puree form.

Consistency of supply and quality must be guaranteed regardless of variations caused by climate, harvest, handling and transport. Since most produce is at present supplied by wild harvest, it is unlikely that mainstream manufacturers will enter the industry in the very near future. It is also unlikely that they will develop products based on native food while raw produce remains at the current prices/kilogram.

Key marketing issues for bushfood producers include:

– A lack of information and educational material on how to use native bushfoods creates some consumer resistance to products.

– Little is known about realistic market potential or about specific market sectors which could support a sustainable industry growth.

Species	Value-added product	Wholesale price per kg (approximate)
Bush tomatoes	Bush tomato chutney	$19–$24
	Bush tomato salsa	$19–$25
	Bush tomato ground	$55–$58
Illawarra plum	Spicy Illawarra plum chutney	$20–$25
	Illawarra plum & chilli sauce	$22–$25
Kakadu plum	Kakadu plum & chilli sauce	$22–$25
	Kakadu plum jelly	$22–$25
Lemon aspen	Lemon aspen curd	$22–$25
	Lemon aspen syrup	$18–$22 per litre
	Lemon aspen cordial	$8–$11 per litre
	Lemon aspen juice	$58–$68 per litre
Lemon myrtle	Lemon myrtle & Akadjura mustard	$13–$15
	Lemon myrtle chilli sauce	$13–$16
	Lemon myrtle dressing	$14–$16 per litre
	Lemon myrtle oil	$40–$50 per litre
Muntries/Munthari	Muntries/Munthari chutney	$20–$25
Native herbs	Mango/Native mint salsa	$22–$25
Native mountain pepper	Pepper leaf mustard	$14–$15
	Red wine/Pepper leaf pasta	$11–$18
	Emu/Pepper leaf pate	$20–$24 approx 700g
Quandong	Quandong jam	$20–$24
Riberry	Riberry & Ginger relish	$22–$25
	Riberry syrup	$10–$12 per litre
Warrigal spinach	Warrigal greens pesto	$22–$25
	Warrigal pasta	$10–$16
Wattleseed	Wattleseed pastas	$16–$20
	Wattleseed coffee mix	$27–$30
	Wattleseed syrup	$20–$22 per litre
Wild lime	Wild lime curd	$22–$25
	Wild lime syrup	$20–$22 per litre
	Wild lime & chilli marmalade	$20–$25
Wild rosella	Wild rosella syrup	$18–$22 per litre
	Rosella & Illawarra plum jam	$17–$20
	Wild rosella cordial	$9–$10 per litre

Species	Plant density per hectare	Yield per plant (kg)	Yield/hectare (t)	Current known plantings	Yield potential of known plantings (t)	Actual demand 1995–96 (t)
Bush tomatoes	8,000	0.5 kg	4.0	12,000	6.0[a]	5.0
Muntries/ Munthari	2,000	1.5 kg	3.0	5,000	7.5[a]	5.0
Warrigal	3,000	2 kg	6.0	5,000	10.0[a]	0.22
Native herbs	8,000 (pot culture)	0.2 kg	1.6	unknown	–	0.04
Native mountain pepper	1,200	unknown	–	5,000	–	2.5
Lemon myrtle	625	2 kg	1.250	5,000	10.0[a]	5.0
Quandong	850	1 kg	0.85	40-50,000	40.0[a]	5.0
Illawarra plum	275	6 kg	1.65	500	3.0[a]	2.5
Kakadu plum	275	10 kg	2.75	unknown	–	2.5
Lemon aspen	275	10 kg	2.75	5,000	50.0[a]	3.6
Riberry	275	15 kg	4.125	5,000	75.0[a]	2.5
Wattleseed	625	1.5 kg	0.93	unknown	–	6.0
Wild lime	625	2 kg	1.25	500	1.0	0.71

[a] Oversupply—actual oversupply of produce will be determined by: years to mature yield for each species; and market growth and resulting increase in demand.

- High prices for raw produce make it difficult to get good prices for value-added products. Many mainstream food manufacturers do not believe that a 'novelty', 'exotic' or 'clean and green' factor justifies higher prices than for conventional foods.
- Food manufacturers and consumers need to know that the food offered is safe to eat. This highlights the need for appropriate food-safety standards.
- Little is known about the most acceptable form of produce. Early market research suggests that there will be more demand for pureed, dried/ground, essences and flavours than for fresh or frozen whole fruits and nuts.

Varieties

There has so far been little genotype selection of improved plants, but the following species are at present the most commonly used and most in demand.

Bush tomato (*Solanum centrale*). Also known as the desert raisin or in some Aboriginal communities as 'akudjura'. A small shrub with grey to green leaves; fruits turn from green to yellow when ripe and dry on the plant to resemble a raisin. It is intensely flavoured with a piquant, spicy taste and can be used as a spice or flavouring addition in most dishes where tomato is used.

Illawarra plum (*Podocarpus elatus*). Also known as brown pine. Evergreen conical tree, a member of the conifer family, which is sometimes used as a municipal street tree or in parks and gardens. Dark green leaves with flowers on both male and female trees; it has blue/black fruits (approx. 20 mm long—ripening during autumn/winter) with an inedible seed attached to the outside of the flesh at the opposite end to the stem. It has a subtle plum/pine flavour.

Kakadu plum (*Terminalia ferdinandiana*). Also known as billygoat, green or wild plum or murunga in East Arnhem land. A medium-sized deciduous tree with flower spikes in early summer followed by oval-shaped, green fruit with a large stone (ripening March-June). It has the world's highest fruit source of vitamin C.

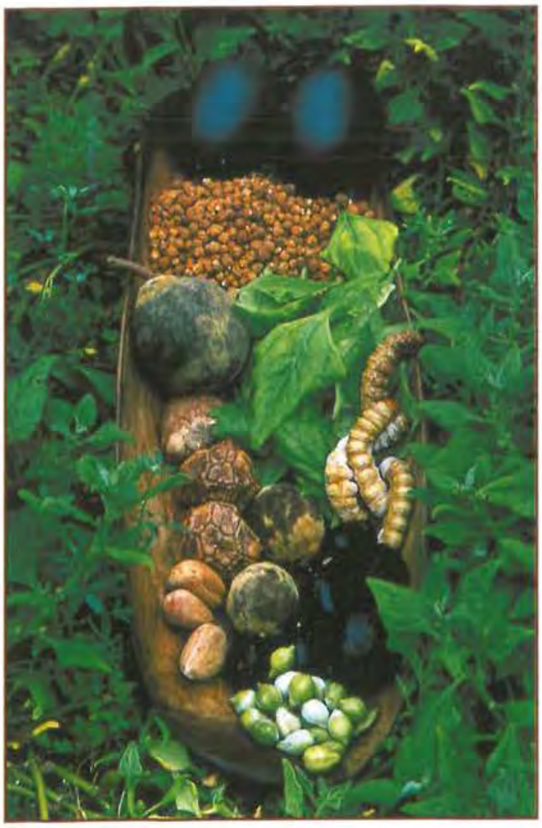
Lemon aspen (*Acronychia acidula*). A medium/tall tropical rainforest tree with dark green, oval-shaped leaves and creamy yellow flowers. The fruit is pale green to lemon coloured (harvest April-July) with a very thin outer skin and juicy, firm flesh.

Lemon myrtle (*Backhousia citriodora*). An evergreen tree of dull green foliage which has a strong lemongrass/lemon scent with white flowers in summer. Its leaves contain essential oils, giving it its perfume and taste; leaves, flowers and seed could all be used in dried, fresh, shredded, ground or crushed form.

Muntries, Munthari (*Kunzea pomifera*). Also known as emu apples, native cranberries, munthari, muntaberry, monterry. Evergreen, creeping shrub with grassy green, rounded leaves and dense, fluffy, white flowers. Small (approx. 10 mm round) green berries become tinged with pink to purple when ripe (generally late summer).

Native herbs (*Prostanthera rotundifolia*). *P. rotundifolia* is a native mint that grows well in cool, moist situations. It is a shrub to 2 metres high in optimum sites. It will not tolerate subtropical conditions and is frost-hardy. Native mint can be alternated with normal use of mint. *Mentha australis* and native aniseeds also have potential as native herbs.

Native mountain pepper (*Tasmannia lanceolata*). Also known as dorrigo, native alpine or snow pepper. Evergreen, medium shrub to small tree with slender, dark green leaves, cream-coloured flowers; berries turn black when ripe in late summer.



More Australian bushfoods

Key messages

- Develop safe food standards.
- Improve industry education, promotion and information.
- Improve production efficiencies and develop sustainable production systems.
- Identify specific market opportunities to maximise industry potential.

Quandong (*Santalum acuminatum*). Also known as the desert, native or wild peach or bidjigal or gudi gudi. Evergreen shrub to small tree with olive foliage; fruits (approx. 15mm round with a large pitted kernel) turn from green to shades of red/yellow/pink when ripe (generally in spring).

Riberry (*Syzygium leuhmannii*). Also known as clove lilly pilly, cherry alder. Evergreen tree with glossy, dark green leaves. Sometimes used as municipal street tree. Red, pear-shaped fruit that ripens in late summer and is strongly clove and spice flavoured.

Warrigal greens (*Tetragonia tetragonioides*). Also known as Botany Bay greens/spinach, New Zealand spinach, warrigal cabbage. A low, leafy, green, ground-cover plant with green leaves that look like an arrowhead.

Wattleseed (*Acacia* spp.). There are probably about one thousand wattle species in Australia, and the Aboriginal people have made various use of many of them. The number of these species suitable for food is much smaller and care should be taken to use only those species known to be safe. Flour of various quality can be produced by roasting and milling the wattleseed.

Wild lime (*Eremocitrus glauca, Microcitrus* sp.). Also known as desert lime, limebush, native cumquat. Dense shrub to medium tree which flowers in July to September, with fruit ripening (in summer) to a lime green to bright yellow colour. It is a juicy fruit which has a West Indian lime flavour.

Processing of bushfoods requires investment in high-grade facilities.

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Wild rosella (*Hibiscus sabdariffa*)

Native rosella (*Hibiscus heterophyllus*). The wild rosella is an introduced species common in northern Queensland and the Northern Territory. It has a tart flavour with a raspberry, rhubarb, plum quality. The petals make jelly and can be used for dessert garnishes. Native rosella is used in the same ways as wild rosella.

Davidson plum (*Davidsonia pruriens*). The Davidson plum is included as a comparison species to Illawarra and Kakadu plums. A slender native of rainforest areas of northern NSW and Qld, the Davidson plum can be interchanged with Illawarra plums. The fruit is ripe when the skin is deep purple and the flesh red. Fruits mature in winter and are relatively easy to harvest as they hang in clusters. Minimal quantities of Davidson plums are used at this stage as it is currently more expensive at $30-32/kg farm gate than Kakadu and Illawarra plum. Plant material is available from several commercial nurseries. It is recommended that details of suppliers be obtained from the grower groups listed as key contacts.

Agronomy

To make a good profit, the producer needs a good knowledge of what management practices will yield good quantities of high quality produce. The management practices that best suit fruit and vegetables my be adaptable to bushfoods in a way that will put commercial production on the right foot from an early stage. The commercial producer should also be able to sell at reduced farm-gate prices so as to encourage demand on the part of processors, whose purchasing will help to prevent the over-supply of some species.

The lack of chemicals registered for use will present problems. R&D is needed to identify which pests and diseases will affect production and to discover and register effective, low-toxicity chemicals which can be applied under appropriate permits.

The seasonal tasks necessary for the production of native food remain largely unmechanised. This means high labour costs, particularly at harvest. However, at present wild harvesters bear heavy expenses for fuel and accommodation, and these costs will be eliminated under commercial operation.

Produce grown from seedlings may not be what the customers want by the time it is harvested and this could be critical for species with a long lead-time like quandong and riberry. There is already a suggestion that buyers will prefer seedless riberries and if this happens, riberries with seeds will be much less profitable.

Nobody yet knows exactly what postharvest handling methods, transport and storage are needed to ensure that quality is main-

Plant density, yield and farm gate price

Plant type	Product	Density/ha	Year of mature yield in brackets. Yield/plant at maturity (kg)	Farm gate price/kg
Groundcovers and Sub Shrubs				
Bush tomatoes	(dried) fruit	8000	(2) 0.5 kg	$15–$25
Muntries/ Munthari	(fresh) fruit	2000	(3) 1.5 kg	$12
Warrigal	(fresh) leaf	3000	(1) 0 2 kg	$8
Native herbs – mint/mentha – thyme – aniseed	(dried) leaf	8000 pot culture	(1) 0.2 kg	 $35 $85 $35
Shrubs				
Native mint – *Prostanthera* spp.		2000	(2) 1 kg	$35
Native mountain pepper	(dried) leaf berry	1200	Not available	$45 $45
Lemon myrtle	(fresh or dried) leaf	625	(3) 1.5 kg	whole leaf $50 ground $55
Wild & native Rosella	(fresh) flower	1500	(3) 40 flowers per 100g	fresh uncleaned $4 cleaned & frozen $8-$12
Trees				
Quandong (2nd grade)	frozen with stone			$8
Quandong (2nd grade)	stone removed	850	(5) 1 kg	$18
Quandong (2nd grade)	(dried) fruit			$40–55
Illawarra plum	(fresh) fruit	275	(5) 6 kg	$16
Kakadu plum	(fresh) fruit	275	(5) 10 kg	$13
Lemon aspen	(fresh) fruit	275	(5) 10 kg	$12
Riberry	(fresh) fruit	275	(5) 15 kg	$12–16
Wattleseed	(cleaned) seed	625	(5) 1.5 kg	$14
Wild lime	(fresh) fruit	625	(5) 2 kg	$10

* Note Wild rosella is not an Australian native species.

tained and shelf-life maximised. This will be particularly important for fresh fruits.

Some native species are known to be toxic— some acacias for example. However, not enough is yet known about this and it will be necessary to make and widely disseminate a list of the species which can safely be planted.

Economics of production

Although commercial production of native plant foods is in its early stages, sufficient demand for some species is beginning to justify commercial production and establish a farm-gate price.

To calculate establishment costs per hectare the following assumptions have been made :

- plantings are of single species grown in monoculture production systems;
- unless otherwise specified, plantings are in ground;
- rows are so spaced as to allow access by small horticultural machinery; and
- spacing in rows allows for a minimally restricted spread of natural canopy.

Planting densities can be increased by vigorous canopy management techniques such as trellising and pot culture. Many people who now produce bushfoods, or are thinking of doing so, prefer permacultural or polycultural planting. However, there is little information available about the costs of production under these systems. The present assessment therefore uses the accepted costs and practices in mainstream horticultural fruit, vegetable or herb production as a basis for calculation.

Plant density per hectare is calculated assuming 100 metre rows, spacings to maximise production, and efficient management practices. Lemon myrtle is assumed to have been trained as a shrub for maximum leaf yield.

The expected *year* of mature or maximum yield is listed in brackets, followed by yield in kilograms. This information has been supplied by current native bushfood nursery producers.

Farm-gate prices are based on price received for product sold to food processors in the 1994–95 and 1995–96 financial years. The prices do not reflect door sales to small restaurants and cottage industry manufacturers.

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Culinary Herbs

Culinary herbs

Kim Fletcher
Shirley Fraser

Introduction

Domestic and industrial consumption of culinary herbs and spices has steadily increased around the world during the past few decades due to changing lifestyles affecting traditional eating patterns, greater consumption of processed and convenience foods, and a return to healthier eating habits in developed countries. Worldwide, demand for reliable supplies of quality material from sustainable production systems has consequently increased, and is expected to continue increasing in the foreseeable future.

Consumption of culinary herbs and spices in Australia has increased in line with global trends and this is expected to continue. Australia is a net importer of dried herbs and spices, producing under 10% of its requirements, but the import data collected by Australian Customs do not differentiate the products sufficiently, and hence are of no real value to growers.. Opportunities therefore exist to provide material both for import replacement in the domestic market, and export sales. The majority of fresh herbs and spices consumed within Australia are produced domestically

With a relatively clean environment, ready availability of suitable land in a range of climatic zones, extensive agricultural and technical expertise, and a history of mechanised production, Australian growers can produce herb and spice crops of the highest quality, and conceivably increase their global market share. Additionally, crops can be produced here in the northern hemisphere 'off season', when overseas buyers are seeking product.

The domestic market is still immature and many growers are currently experiencing difficulties in realising anticipated returns. Large export markets exist but the volume of production in Australia is relatively small. The individualistic nature of Australian growers tending to compete with one another rather than co-operating to increase the pool of product available for these export markets, holds the industry back. The challenge for Australian producers is to meet the larger (predominantly overseas) contracts, providing high quality product at reasonable cost to the buyers, while continuing to maintain themselves in a sustainable production system.

To be a successful grower in the culinary herb industry, you need to possess good organisational skills, be dedicated to the production of the highest quality material possible, be able to work hard or be ready and able to employ others who can, and be willing to actively and openly co-operate with others in your industry, be they growers, processors, wholesale or retail traders, researchers or government organisations.

Markets and marketing issues

It is generally believed that the opportunities to produce tropical spice crops in Australia are limited because of the intensive nature and high cost of production and the existence of established low-cost spice centres in countries more suited to their production. Greater potential exists in Australia for non-tropical spice crops suitable for mechanised production (e.g. coriander, anise, fenugreek), crops suitable for value-adding (e.g. ginger) or crops which target a niche market (e.g. peppercorns).

Fresh and dried herb crops are considered to be a more viable option.

Fresh culinary herbs

The market for fresh-cut culinary herbs is estimated to be worth over $3 million/year.

The demand for clean, flavoursome herbs has been steadily increasing, but the market within Australia is limited. Buyers (including restaurants, supermarkets, greengrocers, produce markets, food processors and caterers) are supplied by market gardeners and specialist herb suppliers either by direct sale or through wholesalers. Returns vary with season and how the herbs are sold (e.g. from $0.50 in summer for a 100 g bunch to $2 in winter for a 50 g bunch).

The current level of interest in fresh-cut herbs from new growers is posing a threat to some established growers, significantly reducing returns on some crops. Potential growers must be aware that price undercutting can create instability in the marketplace and will affect their own long-term viability.

To develop or to maintain/ expand their market share, established and potential growers will need to reduce their costs through increased efficiency and economies of scale, and to seek niche markets such as off-season greenhouse production, gourmet food processors, and 'trendy' herbs such as hot chillies, or grow herb crops in conjunction with other speciality crops, such as fancy lettuce or Asian vegetables. An efficient and effective cold chain system is essential, and retailers require consistent supply throughout the year, and from year to year.

There is some potential for export of top quality herb crops to Northern Hemisphere and Asian markets through established exporters. The market is currently underdeveloped and unstable, but opportunities exist for reliable growers committed to regular supply of quality product. Opportunistic sales are also possible, but individual growers will need to establish themselves on the domestic market before considering export with its additional problems.

Dried culinary herbs

The domestic market for dried culinary herbs is estimated to be 400–500 t/year with a value of

About the authors

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See *Key contacts* for the authors' addresses.

Basil and dill production at Bundaberg, Queensland around $18 million. Dried garlic accounts for an additional 1000 t or more, dried onions a further 1500–2000 t, paprika 600 t and chillies 600 t. The bulk of this product has traditionally been sourced from low-cost countries such as India, Egypt, Turkey, China, Pakistan, Morocco, Eastern Europe, etc. However, we are now seeing companies in countries such as the USA and Germany developing large capital facilities and expanding into the international markets. They will constitute the competition of the future.

The dried market offers the potential to produce a wider range of herbs for direct sale to importers, re-packers, caterers, institutions and food processors. However, buyers require bulk quantities (a minimum of 500–1000 kg/month, or more in some cases; often the buyers' requirements will not be for a monthly delivery, but will vary over the year), and are prepared to pay only $2–5/kg, hence growers will need to develop cost-effective broadacre, mechanised production of top quality crops, and process to specifications if they are to compete. The capital intensive nature of this production chain would be more suited to co-operative ventures or established agricultural enterprises.

Currently, requests from these large buyers are largely unfilled due to insufficient supply.

There is some potential for marketing growers' own brands to speciality outlets, but price competition from established companies may be difficult to overcome.

Other potential markets for dried culinary herbs include herbal tea blends (this market suffers from fluctuating interest, but is currently being investigated by a number of growers and grower groups and would be easy to oversupply), cosmetic manufacturers, and craft material suppliers through direct sale or creative marketing.

Growers should be flexible when thinking of marketing as most 'culinary herbs' have a variety of end uses other than culinary, and may be further processed to other products such as pesto (basil).

Regardless of which market they choose for their product, growers must focus on quality, continuity of supply, quantity (where appropriate) and price. Also, it is important to implement and adhere to QA codes of practice to both establish and maintain a commercial advantage.

Fennel

Key messages

- erratic and immature market not clearly identified and quantified
- long-term investment of time and money required
- need to focus on quality, reliability, quantity and price
- estimated that between 2–5% of participants will remain in industry after 5 years
- competitive advantage with niche marketing, value adding and down-stream processing
- do your homework, and establish a network

Success in the herb and spice industry will depend on identifying and supplying niche markets, as well as maximising opportunities for value-adding and downstream processing. Broadacre mechanised production is essential to control costs if growers are to effectively compete for available industrial markets.

Production requirements

Herbs will grow in a wide variety of soil types and climatic zones. Some of the herbs listed in Table 1 are grown from the frost prone, long cold winter of the New England Tablelands, to the full tropics of the eastern coastal strip. Herbs can be grown anywhere that rainfall is sufficient to allow good growth, or where irrigation water is available.

Generally, it is best to avoid heavier clay soils, as wet soils for extended periods can result in the herb dying from various root rot diseases. Root crops can be more easily harvested and washed if grown in a light soil.

To provide adequate financial returns, herbs need appropriate irrigation to promote sufficient growth for consistent production. Both overhead watering and trickle irrigation are suitable, however under mulch, T-tape is more efficient in terms of water use, and causes less soil splash contamination on the plants. No detailed work on water requirements has yet been published for herbs.

There are no specific topographic requirements for the listed herb types, although a gentle slope will allow good drainage and prevent any wet feet problems. Choose the aspect of the herb field with care, avoiding hot dry prevailing winds, and cold wet southern slopes.

Table 1. Agronomic requirements for selected herbs useful as culinary varieties.

Plant	Sow as [b]	Soil type	Annual/ perennial	Frost sensitive	First harvest [e]	Harvest interval [e]	Plant part [f]	Sold as [g]
Parsley [a]	S/P	NC [c]	A/P	R	3–4 months	4–6 weeks	T, R, S	B
Basil	S/P	NC	A	S	3–4 months	4–6 weeks	T	B
Dill	S	NC	A	R → S	4–5 months	4–6 weeks	T, S	B
Fennel	S/P	NC	P	R	4–5 months	4–6 weeks	T, S	B
Thyme	P	Light	P	R	1–1.5 years	2–3 times per season	L	B
Mint	R	Heavy	P	R [d]	5 months	4–6 weeks	T	F, d
Chillies	S	NC	A	S	4–5 months	once per season	P	D, f
Garlic	B	NC	A	R	9–10 months	once per season	B	F
Oregano	P	NC	P	R	3 months	4–6 weeks	T	B
Rosemary	P	Light	P	R	1.5 years	2–3 times per season	L	B
Coriander leaf	S	NC	A	R → S	3 months	4–6 weeks	L	B
Coriander seed	S	NC	A	R → S	6 months	once per season	S	D
Chamomile	S/P	NC	A	R → S	3 months	2–4 weeks	F	D
Lemon grass	P	NC	P	R [d]	6–8 months	4–6 weeks	T	B

[a] Seed needs pre-treatment before sowing. 24 hours soaking in water removes germination inhibiters from the seed coat.
[b] S seed, P seedlings, R runners, B bulbs
[c] NC not critical. A lighter soil allows cleaner and easier harvesting, a heavier soil will be inherently more fertile. R → S seedlings are frost resistant, the mature plants are frost sensitive.
[d] Will senesce with winter cold. Lemon grass needs to be well bedded down in frost prone areas.
[e] Depending on the climate.
[f] T tops (leaf plus stem), R root, S seed, L leaf, P pod, B bulb, F flower
[g] F fresh, D dried, B both. Larger letter is more important.

Key statistics

The majority of culinary herb production in Australia is at a cottage industry level, consequently few accurate data exist on quantity or value of sales. Where sales are made through produce markets some statistics are available, but these reflect a limited percentage of total production.

Trade figures for imported dried herbs do not reflect the realities of the market as many herbs are grouped together irrespective of their end use. The competitive nature of the industry makes data difficult to access.

Varieties

Consistent best sellers in fresh culinary herb sales are parsley, basil, thyme, chillies, garlic, dill, mints, oregano, rosemary and coriander leaf. The demand for other herbs varies with location, ethnicity of the population, trends, etc. Growers need to be aware of new and emerging trends and plant accordingly. A much larger range of dried culinary herbs is required.

Propagation material (seeds and plants) may be available through general and specialist seed suppliers and propagation nurseries, but growers need access to strains with commercially-superior flavour and appearance, and suitable growth habits and patterns. Long-term commercial advantage will be gained from on-site varietal selection and ongoing breeding programs to increase yields, and to ensure composition is to the buyer's specification. No seed companies in Australia are undertaking this work, but growers can import planting material (most easily seed) from reputable specialist companies such as Richters, Goodwood, Ontario LOC 1AO, Canada (email: orderdesk@richters.com; Web: www.richters.com) [Sole Australian agent—Eshcol Springs Nursery, PO Box 61, Gingin WA 6503].

Herb seedling production is difficult, as the germination rates are often very low, and establishment times can be very protracted (remember that herb types have not been selected for the crop characteristics of rapid and consistent germination, and speedy early growth). However, better field establishment can be achieved with seedling transplants for most species than with direct sowing. If you intend to rear your own seedlings (be warned this is a major undertaking in itself), take these considerations into account and conduct germination tests before you sow, and oversow if the rates fall below 80%.

Direct sowing of some plant types can be successful, and will significantly reduce establishment costs of the crop.

Thyme

Agronomy

The worst problem for most growers in the production of their crops is weed infestation. Consequently, good early ground preparation is essential. Starting the year before your planned herb crop, prepare a seed bed with dedication and sow a leguminous crop suited to your district (see your local agronomist for plant selection and growing techniques). The better the establishment and growth of this green manure crop, the longer the weeds will be held at bay in the herb crop.

Spray kill or plough in the green manure crop before it sets seed, and sow the herb seedlings into the mulch. Do not let weeds set seed in your crop area or nearby. Mow any areas that threaten to set seed and contaminate the crop area. Other weed control strategies include chemicals (none registered for use in herb crops), weed cultivators (the crop must be precision planted), and hand chipping or flame weeding (which may not be available in your area, and will cost hard cash).

Weed mats are recommended, particularly for perennial crops. These can be cost effective even for areas up to several acres. Woven weed mats last for years, are reusable, and allow free exchange of gases and moisture for good soil flora and fauna survival. They pay for themselves by reducing hand-chipping costs within two seasons. Furthermore, they eliminate soil splash contamination on the herb plants.

The young crop needs to be adequately watered to establish well. Weed and insect status should be checked daily during the establishment phase, and continued frequently throughout the life of the crop. Weed problems should be tackled immediately as the job gets harder as the weeds get bigger. If they are allowed to set seed, you have increased your workload for years into the future.

Fertiliser requirement trials carried out at the University of New England suggest that a level of 20 kg P/ha and 40– 80 kg N/ha are needed for optimal herb growth. This is, however, a very generalised statement taking little account of plant type and inherent soil fertility.

Minimal equipment is required for small scale, intensive production. However, to maximise efficiency in broadacre production, normal cultivation equipment such as a Class 2 tractor with hydraulics, cultivation gear or a rotary hoe, weed scuffler, harvester (these are mostly still being developed in Australia and are not yet generally available), trailers, bins etc. for cartage of the harvested crop, are needed. For dried herb production, a forced air, temperature/humidity controlled batch or continuous dryer is essential. If producing your own seedlings a vacuum seeder would be useful, and a controlled environment plastic or glass house.

Spearmint

Pest and disease control

Insect pest problems have so far been relatively minor and transitory, involving species such as green aphids and Helicoverpa (Heliothis) grubs. (Chillies are prone to attack by a variety of insect pests.) This may not continue once larger areas of monoculture crops are grown. Mints and basil can suffer from rust problems in wetter areas.

Harvesting and handling

Washing the herb either before or after harvesting may reduce soil contamination. This can be critical if you have used organic fertilisers such as animal manures. The harvested material must be cooled quickly for both fresh and dried herbs. It is preferable to harvest in the cool of the day to minimise heating, but it is essential that material to be dried is transported and loaded into the dryer within about four hours, or cooled to 4°C as quickly as possible if destined for the fresh

Table 2. Gross margin calculations for oregano (1 ha/100,000 plants)

Year 1		
Variable costs		Cost/ha ($)
Land preparation	workings (3)	300
	chemicals (cost+application)	100
Planting	tractor @ $35/hour	700
	labour @ $12/hour	720
	100,000 seedlings @ $0.10	10,000
	fertiliser (cost+application)	400
Crop care	weeding (site specific)	1000
	irrigation (site specific)	100
Harvesting	(site specific)	100
Transport to processor	(site specific)	100
Total costs		**13520**
Returns		$/ha
Fresh yield/plant (kg)	0.3	
Plant number	100,000	
Harvests	1	
Yield/ha/harvest (kg)	30,000	
Payment $/kg fresh weight	0.3	
Gross return		9,000
Gross margin		−4250
Year 2–4		
Variable costs (per year)		Cost/ha ($)
Land preparation		0
Planting	tractor	0
	labour	0
	seedlings	0
Crop care	fertiliser (cost+application)	400
	weeding (site specific)	1000
	irrigation (site specific)	100
Harvesting	(site specific)	300
Transport to processor	(site specific)	300
Total costs		**2100**
Returns per year		$/ha
Fresh yield/plant (kg)	0.3	
Plant number	100,000	
Harvests	3	
Yield/ha/harvest (kg)	30,000	
Payment $/kg fresh weight	0.3	
Gross return per year		27000
Costs per year		2100
Gross margin/ha/year		24900
Total returns over 4 years		70180
Average return per year over 4 years		17545

market. Serious microbial deterioration will set in if a longer time is taken. The dryer must dehydrate the product quickly at a reasonably low temperature—generally around 40°C, to prevent loss of volatile oils. If destined for the fresh market, the herb will need to be bundled in suitable bunches, or if dried, it will need to be rubbed to remove excess stalks, or sifted, or ground. The buyer's specifications should be your guide.

Economics

Table 2 gives the establishment costs and a gross margin calculation for an oregano crop in the temperate zone of Australia. The calculations are based on an area of 1 ha with a plant population of 100,000.

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Essential Oils

Eucalyptus oil

Richard Davis

Australia is the home of the eucalypt. All the commercial oil-bearing species of *Eucalyptus* are indigenous. Therefore, the raw material for the production of eucalyptus oil is available, and the soil and climate are suitable for the establishment of plantations of oil-bearing species.

Eucalyptus oil has been produced and traded for over 140 years. Although several different types of oil can be produced, it is only the oils rich in cineole that are now produced in quantity. Eucalyptus oil is used in a wide range of pharmaceuticals, cleansers, flavours, and to a small extent, as an insect repellent. Demand for the oil is currently stable.

The oil is easily produced, but the cost of production in Australia is high compared with other countries, even when produced from natural stands thereby avoiding the cost of establishing the crop.

While the demand is static, the production of eucalyptus oil in other countries, particularly China, has increased to a point where the world demand can be met by countries where labour is cheaper. Furthermore, in China the oil is produced as a by-product of the timber industry, thus also avoiding the cost of establishing the crop.

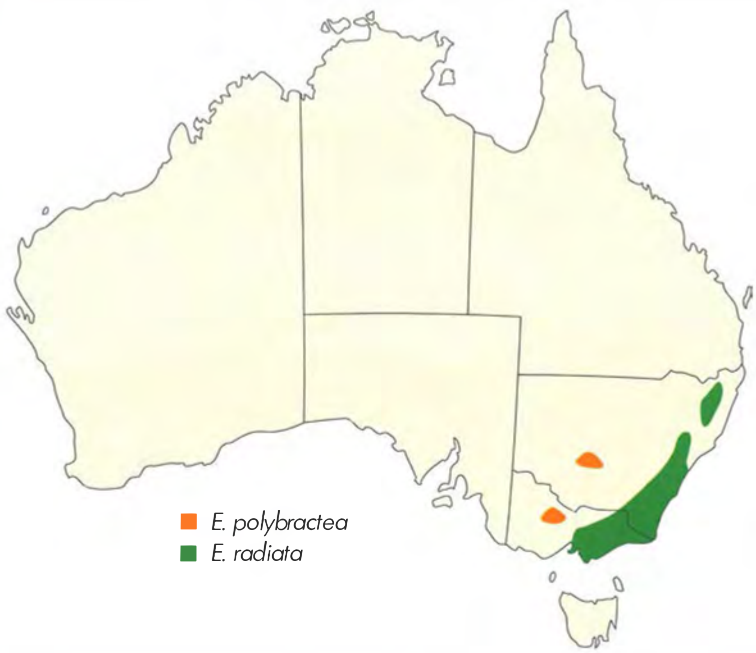
Markets

There are two market categories for eucalyptus oil:

- one for supply of straight oil to the ultimate consumer; and
- one for oil that will be incorporated in other products.

Eucalyptus oil is sold world-wide. Most oil sold in Europe and North America is used in products such as 'Vicks Vaporub', cough and cold remedies, confectionery, etc. Much of the oil sold in Australia and Asia, is used as a pure oil in household products, in inhalations, to alleviate cold symptoms, and as a cleaner, spot remover, massage oil, etc.

The crude oil produced on the farm or in the forest, is sent or sold to a refiner, who redistils, blends to customers requirements, packages and ships to manufacturers or bottlers. The oil is then exported or distributed through the appropriate chain to the retailer. Nowadays, the straight oil is retailed through pharmacies and supermarkets.



Estimated global demand for cineole-type eucalyptus oil is 2500–3000 t/year. Australian production is about 120 t. However, the Australian production is from *E. polybractea* and *E. radiata* var. 'Australiana', while almost all the cineole-type oil produced in other countries is from *E. globulus*. While all the oils conform to the same standards, there is a difference in their character, and this difference allows Australia to retain a share of the world market.

World market price for the standard grade *E. globulus* oil is now about US$3.50/kg in container lots (15 t). The price, while varying to some extent, is now fairly stable after a steady decline. The price is now less than it was 15 years ago. Because of static demand and over-production in China, the price is likely to stay low in the foreseeable future, unless a new large-scale use for the oil is found. Although the higher quality Australian oil commands a higher price, the demand is strictly limited.

Plantation establishment of *Eucalyptus polybractea*

Harvesting eucalyptus into a mobile still

Production requirements

Oil-bearing eucalypts will grow well in many parts of Australia, but work to date shows that *E. polybractea*, the major source of oil, thrives best on the light sandy soils of the western plains of NSW and just west of Bendigo in Victoria.. It grows quite well in rainfall down to 350 mm/year, but would probably do better in slightly higher rainfall areas.

While irrigation would enhance growth, the potential return does not warrant the cost.

E. radiata grows naturally on the Great Dividing Range and the south coast of NSW. It thrives in steep country on a wide range of soil types.

Because it is now essential to mechanise production to be able to produce oil at a saleable price, production from natural stands of *E. radiata* is unlikely. For mechanical harvesting, level to no more than gently sloping land is necessary. Natural forest areas of this type, with good oil-bearing trees as the dominant species, are now rare, which means that plantations are required, or trees planted for soil desalinisation, as in Western Australia, are required.

Varieties/species

The most commonly traded eucalyptus oil is that obtained from *E. globulus*. This oil is readily available because of large-scale planting of *E. globulus* primarily for wood. These trees now also produce oil in commercial quantities.

Simultaneous distillation of two mobile stills

A 300 hp colonial boiler with Dutch oven for burning extracted leaves

Oil of more character is obtained from *E. polybractea*, which also gives better yields and is suitable for mechanical harvesting. The strong lignotuber developed by this species allows coppice growth to be harvested frequently—at about 18-month intervals. This growth can be harvested at ground level.

Several species are being planted for soil desalination. Periodic harvesting of the leaves of these trees will stimulate growth, and therefore transpiration, further helping to lower the saline water table. Species being tried for this purpose include: *E. kochii* ssp. *kochii; E. kochii* ssp. *plenissima; E. horistes*; and *E. loxophleba* ssp. *lissophloia*. All of these eucalypts are native to Western Australian.

CSIRO's Forestry and Forest Products Seed Centre in Canberra, and the Department of Conservation and Land Management (CALM) in Perth are likely sources of seed for all species.

Agronomy

Although all the oil-bearing eucalypts occur naturally in Australia, there are now virtually no remaining areas of natural bush suitable for development for oil production. Therefore, future production must be based on plantations of the desired species, or on harvesting of the leaves of trees grown for other purposes, such as soil desalinisation.

Since it is essential to mechanically harvest plantations, planting in straight rows is desirable. For ease of pest and weed control, sufficient space should be left between the rows for machinery access. Thus, site preparation calls for clearing land that slopes no more than gently, and laying out straight rows, across the slope where possible. The rows should then be ripped as deeply as is practicable and, just before planting, the surface layer to about 25 cm on both sides of the rip broken down to allow the use of planting machines. One or two passes with a rotary hoe should be sufficient to achieve this. Into this ground, 10–20 cm seedlings are planted.

To protect the young seedlings from dehydration, watering at or immediately after planting is essential and watering must continue until the first effective rainfall. In the first few months, the seedlings also need to be protected from livestock.

The equipment required for planting and establishing the young trees is thus:

- a powerful tractor, or preferably bulldozer, with a ripper;

- a cultivator;
- a planting machine; and
- either an irrigation system, or a water tanker with an appropriate water delivery and pump and motor filling systems.

A good source of water is essential.

Seedlings can be bought from a commercial nursery, but unless the scale of operation is quite small this will be too costly. Seedlings therefore generally need to be raised on site, and this calls for the usual nursery facilities of tubes, trays, watering bays, plastic greenhouses and a watering system.

Once planted the trees need to be kept weed free for at least 12 months and protected from insect attack.

Most of the oil-bearing eucalypts do not respond well to fertiliser and thrive in reasonable weather conditions without additional nutrients.

First harvest will depend on time of planting and weather, but except during drought the first harvest can be made 18–24 months after planting. Thereafter harvests are at about 18-month intervals. Over-frequent harvesting will adversely affect the trees.

Because the trees are harvested at ground level, soil will be prone to water and wind erosion. This can be prevented by planting pasture or a crop of some sort between the rows but not close to the trees, or by mulching with leaves from which the oil has been extracted. A. machine will be needed to spread the leaves.

Pest and disease control

Control of weeds in the early planting and regrowth phases is essential. Cultivation is effective in a well laid out plantation where implements can be used very close to the trees. There are also effective herbicides which can be applied close to, or in some cases over, the trees and which do not suppress tree growth.

Livestock, feral pigs and kangaroos can cause damage in the early stages of plantations.

The main insect pests of the mallee species such as *E. polybractea* are sawflies and case moths. Case moths in particular can spread very rapidly and defoliate the trees. This tends to occur when there is a substantial amount of leaf, but not in the early stages of growth or regrowth. A good means of control is to harvest the affected area even if it is not due for harvest.

About the author

Richard Davis is Managing Director of G.R. Davis Pty Ltd (see *Key contacts* for address), the major producer of eucalyptus oil in Australia.

Experience from trial plots indicates that insects and diseases may be a greater problem in establishing plantations in higher rainfall areas, than in the dry areas where *E. polybractea* and other oil-bearing mallees occur naturally.

E. polybractea has not responded well to more fertile soil in higher rainfall areas. Although it is likely that some suitable areas could be found, improved leaf growth would be offset to some extent by the increased cost of insect and disease control.

Key statistics

- World demand for cineole-rich eucalyptus oil–approx. 3000 t/year
- World production potential from existing trees–over 4000 t/year
- Australian production–approx. 120 t/year
- Australian potential–200 t/year

Harvest and processing

Eucalyptus oil is extracted by steam distillation. While there are other methods of extracting the oil, this is the accepted method, stipulated by national and international standards. It is a simple and cheap method.

The oil is confined to the leaves which, after harvest, are placed in a container (still) through which steam can be passed. To produce oil economically, these processes must be mechanised. The mallee type eucalypts, with their capacity to coppice vigorously, are ideal for mechanised harvesting as the whole of the aerial part of the tree can be cut off and placed in the still. The amount of non-oil-bearing stem so harvested is insufficient to warrant separation of leaf and stem and so harvesting requires only simple machinery.

Key messages

- Eucalyptus oil is overproduced
- China can supply world demand
- New use for oil essential

By passing steam through the leaf mass in the still, the oil is vaporised; oil and water vapour are ducted to a condenser and there condensed to liquid oil and water which can be separated by flotation. The oil, being of lower density and, for practical purposes, immiscible with water, floats on the top of the water from which it can be separated easily.

The oil can be stored in drums made of high density plastic or steel (preferably but not necessarily galvanised). Although the oil is 'wet' at this stage, it can be stored without deterioration for several weeks before further processing.

For most uses, the oil needs to be refined, and this is best done by redistillation under reduced pressure. Thus vacuum stills and pumps will be needed.

The initial steam distillation of the oil from the leaves needs to be done close to the harvest area as the cost of transporting leaf more than a few kilometres is too high. Vacuum redistillation is generally not carried out on farm as the cost of the apparatus needed will be too high, unless production on the farm is large or a number of farms share the equipment.

If the crude oil is to be sent on for refining, all that is necessary is to pack it into suitable containers for transport to the refinery. If the crude oil is to be sold as crude oil it should first be dried and filtered.

Steam has to be generated for the distillation of oil from the leaf and because of the low value of the oil at present, the cost of steam production must be kept low. The leaf, after the oil has been extracted, is suitable for this purpose. About 20% of extracted leaf if required as fuel, the rest should be returned to the harvested area to minimise erosion and to retain moisture.

Most oil entering the market must conform to the appropriate national standard. Refining ensures that this is so.

Economies of production and processing

At this stage of the industry's development it is not feasible to set up a viable operation if land and all equipment has to be purchased. However, if land and some standard items of agricultural equipment are already owned, and the cost of establishment of trees is covered by some other project, e.g. trees planted for desalinisation, a profitable operation might eventually be possible. The key to success is the market price. If it remains at its present level it will be impossible to produce oil in Australia at competitive prices.

Establishment costs on cleared land, assuming a heavy tractor or bulldozer is already owned, consists of cost of laying out the plantation, deep ripping and surface cultivation of the rows, planting, watering and weed control. If as suggested above, these costs are not borne by the eucalyptus oil production, then the specific costs to be covered to enable production are: acquisition of a heavy forage harvester, at least three mobile distilling vessels, a boiler, lids, a condenser and oil separator, a pump and motor for circulating the cooling water plus housing for the apparatus if it is not already there. A good water supply is essential. The cost of these items, not new, would exceed $50,000 for a modest plant capable of producing about 15 t of oil per annum. This quantity of oil at present prices would not cover the cost of wages, maintenance and machinery running costs. There can, therefore, be no gross margin for a typical production unit in 1997.

The world market price is set by China. China is moving towards a market economy and the availability of extremely cheap labour might end. However, unless a substantial new use is found for eucalyptus oil, China can more than supply the world demand, and consequently a dramatic price rise in unlikely.

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Key references

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Fennel oil

Lee Peterson

Introduction

Fennel (*Foeniculum vulgare*) is a member of the Apiacae family, formerly known as the Umbelliferae. Other members of this family include parsley, coriander, dill, parsnips and carrots.

The essential oil is produced in canal-like structures formed by glandular cells throughout the plant but with the most prominent canals present in the seed coat.

The production of fennel for its essential oil in Australia has been limited to Tasmania where production began in 1982 and peaked some 10 years later.

The fennel project in Tasmania was developed for the commercially valuable compound, anethole. This compound is used in many anise flavoured beverages popular in European countries and has been traditionally sourced from the fruits of star anise, a member of the magnolia family. The same compound is present in fennel oil, enabling development of a more broadacre approach to its production.

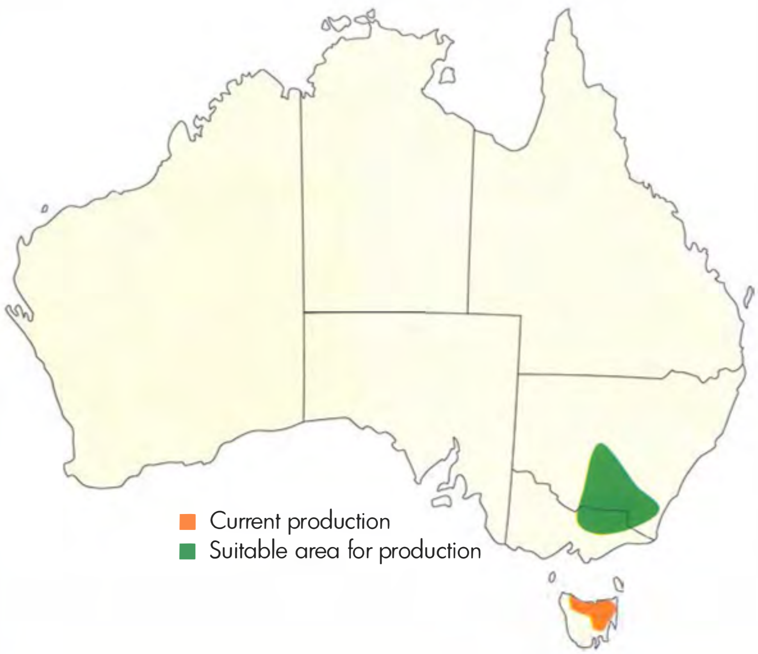
Unfortunately, Australia has not been able to remain competitive with Chinese and Vietnamese star anise production and the remaining fennel production in Tasmania is for the fennel oil in its own right.

Fennel is a deep-rooted perennial which produces 95% of its oil within the coating of its seeds, which are held on one umbel. This has enabled simple grain harvesting and handling systems to be modified and used for harvest. Depending on what sort of oil is required and the transportation arrangements available, the crop can be direct headed or forage harvested and then steam distilled.

Markets and marketing issues

World production of anethole is about 1000 t/year, with China and Vietnam being the dominant producers from star anise. Recent improvements in the continuity and quality of supply from China, as well as price reductions, have seriously affected Australian production of fennel oil for anethole. Production is now less than 1 t compared with a high of 40 t in 1992.

The production of anethole from fennel oil requires specialised rectification equipment to produce the 99% pure product that the market requires.



Present world-wide trends are towards decreased consumption of anethole-based beverages.

The present market for fennel oil is the flavour industry where the balance of anethole with other important flavour components is vital.

While anethole sales in the past have been direct with end-users, fennel oil sales are generally handled through the normal essential oil marketing chain of grower to trader to flavour and fragrance house to end user.

Production requirements

Fennel has been grown successfully on a variety of soil types, from sandy loams to black cracking clays.

Irrigation is essential, particularly during flowering and seed development. Flood irrigation is not recommended as this is reported to cause root disease problems.

Once established, the amount of vegetative material produced by the fennel plant is considerable and plants may grow to over 2 m. It is crucial to maintain cultural practices during the early development of the crop otherwise accessibility becomes difficult and, if applications of fertiliser or pesticides are needed, they must be done so from the air.

Fennel has the added bonus of improving soil structure due to the large amounts of vegetative material that it returns to the soil and its aggressive deep rooting habit. The crop can also be grazed by stock over winter.

Fennel can be harvested with forage harvesting machinery similar to that used for peppermint. However, the crop does not have to be wilted and is cut at a height which removes mainly seed heads. Direct heading of the crop is also successful using regular combine harvesters.

The fennel oil is extracted by steam distillation, a techniques requiring specialised equipment and expertise. Direct heading of seed significantly reduces the volume of herb to be processed. This extends the radius from a distillation facility that the crop can be grown economically.

Varieties

The classification of fennel has in the past been disputed by many researchers, but the general agreement today is that there is only one species, *Foeniculum vulgare* M., with two sub-species, *piperitum* and *capillaceum*.

Recurrent selection programs have been undertaken in India and France to increase seed yield, oil content, oil quality, pest and disease resistance.

About the author

Dr Lee Peterson is an independent consultant offering specialist advice on essential oil crops in particular. He can draw on 12 years experience in research and development, production, marketing and management in the essential oils industry in Tasmania. See *Key contacts* for address.

Dr Lee Peterson and Professor Snow Barlow inspect a fennel crop.

The varieties commercially grown in Tasmania have been a result of a joint program by the Pernod-Ricard company and the University of Tasmania. The program was initiated by Pernod-Ricard in the quest for higher yields of anethole per hectare. A large range of selections is available, depending on the oil characteristics required. In general an oil low in the compound fenchone is required for the flavour market as this is an intensely bitter agent.

Agronomy

Fennel crops can be established easily by direct seeding in spring. with a target density of 10 plants/square metre. Because the seed is small, best results have been obtained using some form of precision seeder. Good seed to soil contact is essential for uniform germination. In general the gemination and initial development of the seedling is slow and no herbicides can be used until the plant has developed at least 3 pairs of true leaves.

Key messages

- Commercial essential oil production requires high capital input and considerable expertise.
- Fennel oil production is not a stand-alone industry; production must be integrated other essential oil crops
- China and Vietnam are major producers.

Key statistics

- Tasmania is the sole commercial producer of fennel oil
- Anethole production from fennel has now ceased in Tasmania
- Maximum fennel oil market from Australia is 10 t

Fennel is a typical long-day plant and will remain vegetative until the day length exceeds 13.5 hours, after which the plant initiates flowers and bolts very rapidly.

Fennel can reach maximum yield in the first year and, with careful maintenance, can maintain that yield for 6–7 years.

Fertiliser requirements are relatively high and require annual soil analysis to monitor changes. To date, no major trace-element deficiencies have developed over a 5-year life span. Nitrogen applications are critical, especially during flowering.

After two years the crop benefits from deep ripping. This alleviates soil compaction, promotes new adventitious root growth, and lowers shoot density. If the shoot density is not checked in later years yield can be decreased.

Agronomic practices are aimed at promoting maximum seed yield and maximum seed size.

Harvest date prediction is not as critical as peppermint as the oil composition is largely determined by the variety. The more important factor is the minimisation of seed loss. The umbels on fennel mature at different rates and it is important not to leave the crop too late as seed lost from the earliest maturing umbels will shatter. Forage-harvested fennel crops can be harvested earlier than direct heading which requires a lower moisture content for successful seed removal and oil extraction.

Pests and diseases

The major disease problem in fennel is a Cercosporidium fungus. This can be managed with early preventative fungicide applications to reduce the level of inoculum. High humidity during flowering will promote Cercosporidium development, such that heavy leaf loss and damage to developing flowers and seed will be sustained.

Late infections can be controlled by fungicide application, but usually the only option is using the less desirable aerial techniques.

The major yield-reducing pests of fennel have been thrips, potato myrid and aphids. Particular care has to be taken with insect pest management during flowering as bee activity is vital for pollination and subsequent seed set.

Harvest, transport and distillation

As mentioned previously, fennel can be either forage harvested or direct headed. The stage of maturity at which each harvest type can commence varies, allowing for considerable flexibility in the harvest period and better utilisation of distillation equipment.

The volumes of crop to be transported to the distillation unit vary greatly between the two methods: heading allows for crops further away from a distillation unit to be economically processed. Conventional grain handling methods can be used for the handling of headed fennel seed, but as the moisture content is much higher than in grain, the product has to be extracted promptly and some handling difficulties may occur. It is important for ease of heading and complete extraction of oil by steam distillation that the seed has the correct moisture content at the time of harvest.

The plant and equipment used for distillation of peppermint can also be used for extraction of fennel oil. If distillation facilities are used for more than one product, it is imperative that tubs and condensers and separators be cleaned between uses.

Once the oil is extracted and separated, the product is relatively stable for many months provided it is stored out of direct sunlight and away from heat. Poly-lined drums are not suitable for fennel: only galvanised or lacquered drums may be used for its storage and transport.

Economics

Fennel crops are established by direct seeding. It is important to use some form of precision seeder to establish the correct plant density. To date seed costs have been relatively low.

The major advantage of fennel is its robust perennial nature. Proper maintenance has allowed crops in Tasmania to yield nine commercial harvests.

As with most essential oil crops the major costs are those for the harvest, transport and distillation. On-farm costs are limited to fertilisers, pest and disease control, and irrigation, and for slashing the stubble after harvest and some form of ripping or interrow cultivation in subsequent years to maintain vigour.

Contractors can be used for direct heading of fennel, but forage harvesters must be modified if the crop is to be collected in this fashion.

Capital outlay for distillation equipment such as boilers, condensers, separators, and tubs is considerable. In general, even with second-hand equipment, set-up cost have been in the order of $150,000–250,000 for a regional facility.

Mobile distillation units have been trialed in Australia but the strict regulations covering boilers have led to both economic and strategic failure.

The following table is a typical gross margin analysis for fennel oil production

	Year 1	Year 2 onwards
Oil yield (kg/ha)	100	100
Price	22	22
Gross income	2200	2200
Materials		
Fertiliser	110	120
Disease control	120	120
Weed control	135	40
Pest control	20	20
Tractor and plant		
Planting	95	
Fertiliser application	18	18
Disease control	15	15
Weed control	30	15
Irrigation	220	220
Slashing	15	15
Harvest and distillation	550	550
Total variable costs	1328	1133
Annual gross margin/ha	872	1067

It should be noted that the gross margin is very sensitive to yield and price changes. Production costs tend not to vary greatly. This gross margin is based on the grower selling direct to traders.

Harvesting fennel using modified combine harvester, Coal River Valley, Tasmania

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Key references

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Lavender

Rosemary Holmes

Introduction

Lavender is a very old herb which was used for disinfectant, antiseptic, relaxing, culinary, medicinal and therapeutic purposes as far back as Roman times.

There is an increasing demand in Australia for the use of lavender and Australia can grow a quality crop equal to that produced in France. However, the Australian industry faces strong competition from cheap imported lavender. Large quantities of oil and dried lavender are imported each year.

The key strengths of growing lavender in Australia are our climate and our ability to produce high quality products. A cool climate is preferred but lavenders are now being tested in higher altitudes in Queensland.

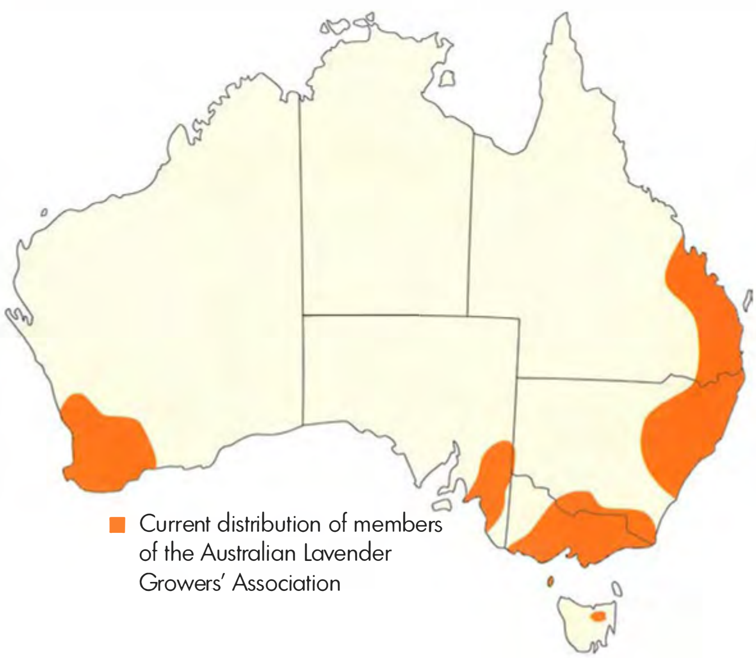
Lavender is grown for the fresh flower market, dried flower market, on or off the stem, oils and value-added products for the kitchen, skin care and handicrafts. Many more essential oils are used for aromatherapy, natural therapy centres, craft designs and culinary purposes. Some 1.8–2 t of oil are exported each year.

Although there are many newcomers across Australia, the industry is still embryonic. There are no major production centres. The Australian Lavender Growers' Association formed in 1995 has about 320 members and is seeking information to set up a detailed data base for the industry. The main competitors for Australian producers are the well-established European growers who have been growing quality lavender for over a century.

Markets and marketing issues

There is no one principal market for lavender in Australia, as most people have only been growing since the 1980s although the Bridestowe Lavender Estate in northern Tasmania has been growing lavender and supplying high quality oil for over eighty years. Most other growers are developing their own niche on local markets.

There is a demand for loose or stripped lavender for the diverse requirements of the craft market, hospitals and nursing homes.



Much of Australia's lavender oil for aromatherapy and craft uses is imported. Stripped lavender, often of lower quality, is also imported from countries such as Bulgaria or Spain for craft purposes.

The average pricefor dried lavendar, depending on the country of origin, ranges from $10 to $16.00/kg. Some loose lavender of appalling quality is imported for $8.00/kg.

Australian production is of superior quality, but production costs are also higher. Stripped lavender grown in Australia is sold for $18 to $22/kg wholesale or $22 to $38/kg retail, depending on the variety, colour and state in which it is sold. Lavender on the stem sells for $1.20 to $2.00 wholesale/kg or $3.80 to $6.00/kg retail, again depending on variety and stem length.

Lavender oil distilled by mainland growers is being sold in 10–15 mL bottles for $7–18/bottle retail, again depending on the variety and quality. The second-grade oil known as lavandin oil has a lower price but is used in soaps, toothpaste, and aromatherapy.

Production requirements

Lavenders prefer a cold climate and some varieties will tolerate frost and snow. Some will grow well in coastal areas. Some will survive well inland and others will grow on sub-tropical islands, since there is such a variety of types of lavender. Several different varieties should be tested to see what will grow best in each micro-climate.

Most growers are scattered across New South Wales and Victoria but farms are developing in the southern sections of South Australia and Western Australia and small areas are beginning in Queensland and Tasmania. Australia's largest grower is the Bridestowe Estate in northern Tasmania..

Lavender is hardy, herbaceous, evergreen plant that can thrive under a wide range of soil and climatic conditions but it prefers a neutral to alkaline soil of pH 7–7.5. It will tolerate drought once the roots are established in the ground. There may be a need to drip feed or irrigate young plants if there is a dry spell, but this is not necessary under normal climatic weather patterns. In a very dry region there may be a need to irrigate for the first year until the roots do become fully developed.

It is essential that lavenders have good drainage, are in full sun and are not planted near eucalyptus trees or any other oil-producing plants as this can interfere with the quality of the oil.

Hand sickle used to harvest lavender

About the author

Rosemary Holmes, in partnership with Edythe Anderson, owns the Yuulong Lavender Estate at Mt Egerton, near Ballarat in Victoria (see *Key contacts* for address). Yuulong holds the National Registered Collection of Lavenders, which contains over 84 varieties. Yuulong has been growing lavender since 1981 and, with an interim committee, its principals were responsible for the formation of the Australian Lavender Growers' Association.

Varieties/breeds

Some of the species, cultivars and hybrids developing in Australia for fresh/dried flowers and oil include:

Lavandula × *augustifolia* 'Vera'

Lavandula × *augustifolia* 'Bosisto'

Lavandula × *intermedia* 'Seal'

Lavandula × *intermedia* 'Grosso'

Lavandula × *intermedia* 'Miss Donnington'

Lavandula intermedia 'Yuulong'

Key messages

- Full sun.
- Good drainage essential.
- Prune hard each year and lime in autumn.
- Do not use too much fertiliser.

Lavandula latifolia

Lavandula dentata var. candicans.

Many new lavenders from New Zealand and England are being trialled.

The Australian Lavender Growers' Association can provide lists of nurseries which specialise in lavender and propagate correctly labelled plants.

Agronomy

Lavender will tolerate poor soils, but it is essential to have a total soil analysis done before planting if the crop is to be managed professionally. The area should be ploughed well and lime or dolomite added if the pH is low. Benched rows ensure good drainage. If the site is sloping, they should be on the contour of the hillside to prevent soil erosion. The area between rows can be grassed and mowed in spring and summer. Weed control will be necessary.

Tying lavender in bunches after harvest

If rabbits prove a problem, an individual guard around each plant or the netting of the entire area will be necessary, making certain that the netting goes down into the soil. Rabbits, kangaroos and wallabies do not usually eat the young plants, but will do so in times of drought. They tend to dig up the freshly planted bushes and leave them lying on the ground.

The fertiliser requirements of lavender will depend on the total soil analysis, but it does not need much fertiliser. Potash enhances good floral blooms. Fertilise in the spring.

Bushes are fully mature in about three years depending on the variety, but a small amount of lavender can be harvested from the first year.

Pests and diseases

There are few diseases that effect lavender in Australia.

The spittle bug (*Philaenus spumarius*) may be detected, usually in the spring, as small areas of spittle on the stem of the plant. A small green insect can be found in the spittle but these do little damage and usually can be ignored.

The alfalfa mosaic virus can cause yellow patches on leaves but it will not destroy the plant and aphid control can be investigated if required.

Economics of production and processing

Establishment costs include the purchase of land, if not already owned; a tractor and trailer will be needed for harvesting and a ride-on mower, if grassing between rows. New growers should budget for a total soil analysis, which could cost between $80 and $120 depending on the company.

Purchase of plants in 50 mm pots can cost between 90 cents and $1.20. Plants in 75 mm pots average $2.50.

First grade lavender oil for the perfume industry will attract a higher price than the second-grade oil used in aromatherapy.

Lavender yields per bush –
L. × allardii = 8–10 bunches per bush

L. 'Seal', 'Grosso', 'Yuulong' = 5–7 bunches per bush

L. 'Vera' or smaller varieties = 3–4 bunches per bush

Wholesale prices, depending on packaging, average:

Fresh flowers $2–$3 per bunch

Dried flowers $1.50–$2 per bunch

Stripped lavender $18–$22/kg

Retail prices, depending on packaging, average:

Fresh flowers $4–$6 per bunch

Dried flowers $4–$6 per bunch

Stripped lavender $23–$30/kg, depending on the quality

Lavender oil prices;
10 mL bottles average $7–$8 each

15 mL bottles average $10–$18 each

100 mL bottles average $45–$80 each, all depending on quality.

Hanging bunched lavender to dry

Retail prices vary between areas and States.

Key contacts

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Key references

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McLeod, Judyth *Lavender, Sweet Lavender*

Denny, E. F. K. *Field Distillation for Herbaceous Oils* PO Box 42 Lilydale 7268.

Proceedings International Lavender Conference, Ballarat, Victoria, November 1996 (available from The Treasurer, TALGA, Elmore Lavender Farm, Campaspe St., Elmore 3558)

A list of small publications is also available from TALGA

Peppermint oil

Lee Peterson
Fred Bienvenu

Introduction

Peppermint oil is obtained from the leaves of the perennial herb, *Mentha piperita* L. a member of the Labiatae family. This family includes many well-known essential oil plants such as spearmint, basil, lavender, rosemary, sage, marjoram and thyme. The peppermint plant is a summer-growing perennial with upright square stems reaching a metre in height at maturity.

The oil is found on the undersides of the leaves, is extracted by steam distillation and is generally followed by rectification and fractionation before use. Its major end-uses are in toothpaste and mouthwashes, chewing gum and food flavourings.

World production is more than 4000 t/year, with the USA accounting for 90% of this and being, in addition, an importer and re-exporter.

The increase in world-wide demand is currently running at about 5% a year, predominantly as a result of Asian market expansion

The environmental conditions under which peppermint is grown are critical to the quality of the oil produced and limit the areas suitable in Australia to Tasmania and Victoria. Long day lengths with warm to hot conditions and cool nights are required for the right balance of oil compounds to be produced during the growing phase. Most of Tasmania is therefore suitable and in Victoria the agricultural areas adjacent to the alps in the north-east of the State provide the right growing conditions.

Production has been under way in both these regions for many years and is currently expanding in the Victorian region. Production techniques are based to a considerable extent on U.S. practices and require a high level of capital input and expertise to produce a saleable product.

Markets and marketing issues

Prices in world markets are dictated by conformity with the characteristics of U.S.-produced oils, which differ from region to region. 'Lower quality' oils typically command a market price of about $A30/kg, whereas 'higher quality' oils can fetch up to $A60/kg.

The buyers' primary concern is the quality and flavour of the product and the consistency from year to year.

About the authors

Dr Lee Peterson is an independent consultant offering specialist advice on essential oil crops in particular. He can draw on 12 years experience in research and development, production, marketing and management in the essential oils industry in Tasmania.

Fred Bienvenu, a researcher with Agriculture Victoria, has some 26 years experience in research and extension, 19 of these in essential oils and natural product research and industry development.

See *Key contacts* for the authors' addresses.

Harvesting peppermint in the Owens Valley Victoria, February 1997

This largely stems from the need for a consistent taste in the end-product formulated and delivered to customers.

The world-wide trade in peppermint oil is generally from growers to traders who may blend or rectify the oils from many growers or even regions to provide a consistent product to the flavour and fragrance houses which then supply pre-formulated product to the manufacturer.

Sales direct to flavour and fragrance houses and manufacturers do occur but require considerable long-term marketing commitment and well established production history.

The level of pesticide residues in the oil is now a key marketing issue. The top end of the market is very discerning and well equipped for residue detection.

Production requirements

Climatic constraint of areas suitable for production has already been mentioned. A major factor in this context is to minimise the production of less desirable compounds, in particular menthofuran.

Peppermint requires a relatively free-draining soil type with a pH of 6–6.5. Areas that lie wet in winter will not perform vigorously and plants may even die. Inundation during the growing season has even greater harmful effects.

The crop has high water demands in the summer. Crops are currently grown under managed flood, high pressure and low pressure irrigation systems. It is the ability to adequately irrigate which normally limits the growth or expansion of peppermint areas.

Pest and disease management are paramount and efficient broadacre spray equipment is a prerequisite.

Key statistics

- World production 4000 t/year
- World consumption increasing by 5% per year
- Australian production 30 t

Harvesting uses conventional forage harvesting technology but distillation of the oil requires specialist equipment and expertise and needs to be regionally based as large volumes of material must be processed.

Varieties

Mentha piperita L. is a sterile, perennial herb and therefore must be propagated vegetatively.

Two main selections are currently in commercial usage throughout the industry. Black Mitcham is the original cross. It is highly valued but susceptible to a soil-borne fungal disease, verticillium wilt.

Peppermint before harvest in the Owens Valley, Victoria

Todd Mitcham is a more wilt-tolerant selection which now forms the bulk of the world's production.

Both selections are present in Australia where, to date, verticillium wilt has not been detected.

Agronomy

Using stolons from a nursery site of 1 ha, a cropping area of 7–10 ha can usually be achieved the following year.

As peppermint is a perennial crop, pre-planting weed control is imperative for the long-term viability of the crop. A well-planned fallow and weed eradication program before planting is therefore strongly recommended.

Specialised lifting equipment is used in Victoria and Tasmania to lift plants and remove soil. In Victoria, a specially designed planter is used to place stolon fragments evenly in rows. These rows rapidly close over and form a dense canopy in summer. In Tasmania lifted stolons are spread using modified muck spreaders followed by a light discing. Both planting processes work well.

Strong healthy planting material is essential for correct density of established crop.

Fertiliser rates are generally high, as development of the maximum number of leaves and their retention through to harvest is the target. Frequent nitrogen applications are required through the growing season and careful maintenance of soil fertility is needed to ensure the crop remains productive. A commercial crop correctly maintained will yield well for at least 5 years.

Because this plant is very succulent, proper timing of all operations is critical for the retention and maximisation of oil glands in the leaves. Oil yield will decrease rapidly if the plant is subjected to either physiological or pathological stress.

Pest, disease and weed control

The most significant disease problem encountered with peppermint is a rust fungus which, if left unchecked, will totally defoliate the plants.

The current method of control is to use the fungicide 'Tilt' at strategic times in the life cycle of the rust fungus. The other important factors for control are efficient spray application, removal of any areas that are hard to spray and removal of rogue plants.

Pest problems encountered in Australia include cut worms, twospotted mite, brown vegetable weevil and wingless grasshopper,

Weed control programs must be strictly maintained to reduce plant competition but more importantly to eliminate oil contamination. There are herbicides registered for use in peppermint crops.

Harvesting, transport and distillation

The timing of harvest is critical to the quality of the oil. In Tasmania and Victoria an extensive pre-harvest sampling program is employed to schedule harvesting of all peppermint crops. This sampling examines changes in oil composition from early January onwards.

Peppermint crops are mown using conventional hay mowers or windrowers. It is very important not to bruise any of the leaves at any time during harvest as this will result in oil losses.

Once the cut herb is wilted it is chopped directly into a distillation vessel, usually referred to as a tub, using a forage harvester. The correct moisture content of the herb is essential for complete and economic oil extraction.

The tubs are then transported to the distillation facility where either wet or superheated steam is passed through the herb and the resulting steam and oil vapour are condensed and separated.

Condensing and separation equipment should be manufactured from stainless steel and general processing hygiene followed to ensure no contaminants are present.

In general, the most-economic units distil five or more tonnes of herb at a time. The time for oil extraction varies depending on the type of steam source, the herb weight and the moisture content.

Most distillation units are diesel-fired but wood-fired units are used in Tasmania with success.

Once the oil is separated, the product is relatively stable for many months provided it is stored out of direct sunlight and away from heat. Epoxy-lined and galvanised drums are the commonly used storage and transportation units.

Economics

The costs of establishing a peppermint crop are considerable because propagation is vegetative, as described above. In general, a minimum area of 5 ha is needed within an existing essential oil distillation region of radius 30 km. For a distillation region to be viable a minimum of approximately 80 ha is necessary.

Capital outlay is considerable for dedicated equipment such as boilers, condensers, separators, tubs, and planting equipment. In general, even using second-hand equipment set-up costs have been in the order of $150,000–250,000 for a regional facility.

The following is a gross margin analysis for a typical Tasmanian or Victorian peppermint crop of 5 ha or greater.

	Year 1	Year 2 onwards
Oil yield (kg/ha)	55	70
Price	40	40
Gross income	2,200	2,800
Materials		
Fertilisers	295	295
Disease control	285	285
Weed control	130	130
Plant material	100	
Tractor and plant		
Planting	115	
Fertiliser application	18	18
Disease control	15	15
Weed control	10	10
Mowing	10	10
Irrigation	290	290
Contract		
Planting	75	
Harvest and distillation	550	550
Total variable costs	1893	1603
Annual gross margin	**307**	**1197**

It should be noted that the gross margin is highly sensitive to yield and price changes. Production costs tend not to vary greatly.

Key messages

- Environmental/climatic conditions critical for saleable product
- Capital costs high due to specialised machinery and extraction facilities needed
- Field expansion costly and slow

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Spearmint oil

Lee Peterson
Fred Bienvenu

Introduction

The two main types of commercial spearmint oil are obtained from the leaves of the perennial herbs, *Mentha spicata* L., more commonly known as native spearmint, and *Mentha cardiaca* L., Scotch spearmint. These are members of the Labiatae family, which includes many well-known essential oil plants such as spearmint, basil, lavender, rosemary, sage, marjoram and thyme. The spearmint plant is a summer-growing perennial with upright square stems reaching a metre in height at maturity.

The oil is found on the undersides of the leaves, is extracted by steam distillation and is generally followed by rectification and fractionation before use. Its major end-uses are in toothpaste and mouthwashes, chewing gum and food flavourings.

Spearmint is produced mainly in the USA with some recent development in China and South America. The world market for spearmint oil is approximately 1500 t/year.

The environmental requirements for spearmint cultivation are not as narrow as those for peppermint. Nevertheless, as the general growing requirements, management practices and harvesting techniques are the same for both crops, spearmint is grown in the same production localities as peppermint.

Production in Australia has been very limited, with a maximum of 1500 kg produced in Tasmania in the early 1990s. This production has been based purely on native spearmint. Collaborative research is currently under way in Victoria and Tasmania examining the feasibility of Scotch spearmint production.

One of the main advantages of spearmint production is the ability to integrate the crop with other essential oil production. This system allows for considerably increased utilisation of plant and equipment, thereby offsetting the capital attributed to each enterprise.

Markets and marketing issues

While the production of spearmint oil world-wide is smaller than peppermint oil, it is substantial and increasing.

Many oral care products are now using a combination of spearmint and peppermint oils to 'soften' the flavour and appeal to a wider market. In some cases blends may use equal proportions of the two oils.

The price of spearmint oil fluctuates year to year, with native spearmint at 20–40% lower than peppermint oil and Scotch spearmint 0–10% higher than peppermint oil. Maximum prices are achieved only if the major oil components, carvone and limonene, are in the correct balance with other flavour components.

Buyers are primarily concerned with the quality of the product as determined by the characteristics and consistency of the oil and its organoleptic (smell) properties. The need for consistency from year to year derives from the requirement for consistency of taste in consumer end-products.

The world-wide trade in spearmint oil is generally from growers to traders who may blend or rectify the oils from many growers or even regions to provide a consistent product to the flavour and fragrance houses which then supply pre-formulated product to the manufacturer.

Sales direct to flavour and fragrance houses and manufacturers does occur, but requires considerable long-term marketing commitment and well established production history.

The level of pesticide residues in the oil is now a key marketing issue. The top end of the market is very discerning and well equipped for residue detection.

About the authors

Dr Lee Peterson is an independent consultant offering specialist advice on essential oil crops in particular. He can draw on 12 years experience in research and development, production, marketing and management in the essential oils industry in Tasmania.

Fred Bienvenu, a researcher with Agriculture Victoria, has some 26 years experience in research and extension, 19 of these in essential oils and natural product research and industry development.

See *Key contacts* fo rthe authors addresses.

Production requirements

Spearmint requires a relatively free-draining soil with a pH around 6.5. Areas that lie wet in winter will not perform vigorously and plants may die.

Spearmint has high water requirements during summer. Crops are currently grown under managed flood, high pressure and low pressure spray/sprinkler irrigation systems.

Pest and disease management are paramount and efficient broadacre spray equipment is a prerequisite.

Harvesting uses conventional forage harvesting technology but distillation of the oil requires specialist equipment and expertise and needs to be regionally based as large volumes of material must be processed. This impinges on transport costs and the need to process quickly to minimise product deterioration.

Spearmint differs from peppermint in that a healthy crop will regularly produce two harvests each season whereas peppermint usually produces only one harvest. In general, experience has shown that it is better to concentrate on maximising the oil potential for one harvest because of the high costs of harvest and costs and the additional costs of disease management with double harvest.

Varieties

Mentha spicata L. and *Mentha cardiaca* L. are sterile perennial herbs, and therefore must be propagated vegetatively.

Mentha spicata L. is characterised by a high carvone content which accounts for 60–70% of the total oil analysis, accompanied by a limonene content of 8–15%. The odour profile of native spearmint is a fresh and green with very high floral topnotes. The body of the oil is warm and herbaceous.

Scotch spearmint *M. Cardiaca* just before harvest

The carvone content of *Mentha cardiaca* L. is also 60 and 70%, but typically it has a higher limonene content of up to 20%. The oil also has a menthone content of up to 2%. This is the prime indicator of Scotch spearmint oil.

The odour of the oil is light, fresh, and diffusive, with an ethereal topnote and a woody, rapid body expansion. The body of the oil is typically very sweet.

Agronomy

Generally a nursery site of material is planted from lifted stolons in early winter. This is typically 1–2 ha in area. From a nursery site a plant-up ratio of 8–10:1 can usually be achieved the following year.

As spearmint is a perennial crop, pre-planting weed control is imperative to the long-term viability of the crop. A well-planned fallow and weed eradication program before planting is therefore strongly recommended.

Key statistics

- World production is 1500 t/year
- World consumption is increasing
- Australian production is only in its infancy

The same specialised lifting equipment as is employed in Victoria and Tasmania to lift peppermint plants and remove soil can be used, provided the machinery is cleaned well to avoid cross contamination

Strong healthy planting material is essential for correct density of established crop. Stolons are typically the thickness of a pencil and white to pale green-brown. Black stolons should not be planted as this colour indicates disease or poor condition.

Fertiliser rates are generally high, as development of the maximum number of leaves and their retention through to harvest is the target. Frequent nitrogen applications are required through the growing season and careful maintenance of soil fertility is needed to ensure the crop remains productive. A commercial crop correctly maintained will yield well for at least 5 years.

Pest, disease and weed control

The most significant disease problem encountered with spearmint is a rust fungus which, if left unchecked, will totally defoliate the plants. The current method of control relies on use of the fungicide 'Tilt' at strategic times in the life cycle of the fungus. Other important factors in control are efficient spray application, and the removal of rouge plants and areas that are difficult to spray.

Scotch spearmint appears to be more sensitive to rust attack than the native spearmint, but both are prone to significant oil loss if the rust is left unchecked.

Pest problems encountered in Australia include cut worms, twospotted mites and the wingless grasshopper.

Weed control programs must be strictly maintained to reduce plant competition but more importantly to eliminate oil contamination. Very few herbicides are registered for use in spearmint crops. Growers should seek specialist advice before applying any pesticides.

Harvesting spearmint in the Fingal Valley, Tasmania

Harvesting, transport and distillation

The timing of harvest is not as critical to the quality of the oil as it is with peppermint and maximisation of oil yield is generally more important. Nevertheless, in Tasmania and Victoria an extensive pre-harvest sampling program is essential to ensure optimum quality oil.

Spearmint crops are mown using conventional hay mowers or windrowers. It is very important not to bruise any of the leaves at any time during harvest as this will result in oil losses.

Once the cut herb is wilted it is chopped directly into a distillation vessel, usually referred to as a tub, using a forage harvester. The herb must have the correct moisture content for complete and economic oil extraction.

The tubs are then transported to the distillation facility where either wet or super-heated steam is passed through the herb and the resulting steam and oil vapour are condensed and separated.

Condensing and separating equipment should be made from stainless steel, and general processing hygiene followed to ensure no contaminants are present.

Key messages

- Integration with existing essential oil production is essential
- Capital costs are high due to specialised machinery and extraction facilities needed
- Field expansion is costly and slow

In general, most economic units distil five or more tonnes of herb at a time. The time taken for oil extraction varies depending on the type of steam source, the herb weight and the moisture content.

Most distillation units are diesel fired but some wood fired units are used in Tasmania with success.

Once the oil is separated the product is relatively stable for many months provided it is stored out of direct sunlight and away from heat. Epoxy-lined and galvanised drums are the most commonly used storage and transportation units.

Economics

The costs of establishing a spearmint crop are considerable because propagation is vegetative, as described above. In general, a minimum area of 5 ha is needed within an existing essential oil distillation region of radius 30 km.

Capital outlay is considerable for dedicated equipment such as boilers, condensers, separators, tubs, planting equipment. In general, even with second-hand equipment set-up costs have been in the order of $150,000 to $250,000 for a regional facility. Consequently, spearmint production is at present viable only if integrated with existing essential oil production regions.

The table on the following page is a gross margin analysis for a typical Tasmanian or Victorian spearmint crop of 5 ha or more.

It should be noted that this gross margin is highly sensitive to yield and price changes. Production costs tend not to vary greatly.

	Year 1	Year 2 onwards
Oil yield (kg/ha)	60	75
Price	35	35
Gross Income	2,100	2,625
Materials		
Fertilisers	295	295
Disease control	285	285
Weed control	130	130
Plant material	100	
Tractor and plant		
Planting	115	
Fertiliser application	18	18
Disease control	15	15
Weed control	10	10
Mowing	10	10
Irrigation	290	290
Contract		
Planting	75	
Harvest and distillation	550	550
Total variable costs	1893	1603
Annual gross margin	**207**	**1022**

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Proceedings of the Essential Oils Planning Workshop, RIRDC, June 1996

Tea tree oil

John Murtagh

Introduction

The production of oil from tea tree is one of the few agricultural industries, excluding forestry, that uses an Australian native plant. Several species of *Melaleuca* can be used to produce Australian tea tree oil, but most plantations use *Melaleuca alternifolia.* The industry originally harvested trees growing naturally in bush areas, but plantations were established when the demand for oil exceeded the capacity of bush production. The first successful plantations were established in the mid-1980s and the shift from bush to plantation production created a need for new technology to address cultural issues such as establishment, and weed and insect control.

Australian tea tree oil is marketed as a natural antiseptic and antifungal agent. It is used in a wide variety of health-care products for topical application. While there is ample anecdotal evidence as to the effectiveness of the oil, the industry can make only limited claims on the efficacy of the oil until they can be supported with evidence from clinical trials. Progress on this aspect is slow because of the cost of trials and the small size of the industry.

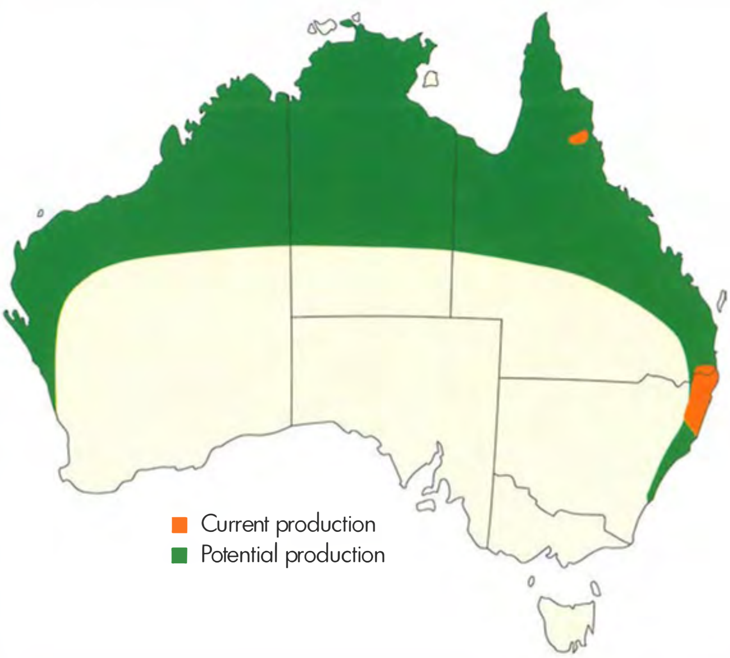
The production of oil has increased from a base level obtained from bush stands of about 12 t/year to 180–220 t in 1996–97. Concurrently, the farm-gate price of oil increased from $15/kg to $45–55/kg.

Once established, tea tree is a hardy perennial crop which survives well. However, production is very sensitive to management, and yields can easily drop to less than 50% of potential with poor management.

Markets and marketing issues

Reflecting the introduction of plantations, the production of oil has increased markedly over the past decade (Fig. 1). Further increases are assured as new areas, already planted, come into production. Coinciding with the increase in production, the farm-gate price of oil increased to $55/kg in 1989–90 and has moved in the $45–55/kg range over the past 8 years (Fig. 1).

One study estimated that the equilibrium price for oil was $34/kg with a total oil production of 360 t/year; the equilibrium being between the industry demand curve and the supply curve from existing producers in 1993. To some extent these projections have been overtaken by the creation of new markets, but the $34/kg price should be kept in mind.



It is difficult to obtain accurate information on marketing, but it is commonly accepted that more than 80% of Australian production is exported. Most is shipped as bulk oil. The oil is sold both as neat oil in small bottles, and in a wide range of toiletry and health-care products. Overseas production is currently very low, but there are indications that a number of countries will soon produce a significant volume of oil.

Production requirements

The oil is extracted from tea tree leaves and the level of production depends equally on the yield of leaf and the concentration of oil in leaves at harvest time. The yield of leaf is strongly correlated with the overall growth and yield of biomass. The oil has many chemical constituents and the international standard (ISO 4730-1996) requires oil to have more than 30% terpinen-4-ol and less than 15% cineole. It is generally accepted that terpinen-4-ol is an active ingredient in the oil and a high concentration is desirable. The cineole concentration is more controversial. Though there is no scientific justification to do so, the market seeks the lowest possible concentration of cineole and pays a premium for oil with less than 5% cineole.

Tea trees grow best with ample supplies of heat and moisture. Tropical and subtropical districts provide the required temperatures, and plants approach dormancy when the soil temperature is below 17°C. The trees are susceptible to frost damage. Light to moderate frost will affect only young growth, but a severe frost will cause extensive defoliation and kill some trees.

The plants have a poor regulation of water use and growth will decline markedly as the soil begins to dry out. However, shallow groundwater can maintain much of the turgidity and growth of plants when the topsoil dries out. Hence, the need for irrigation is determined by both the local rainfall and groundwater supplies. The trees are tolerant of wet conditions, and given the need for good water supplies, plantations are commonly situated in high rainfall districts (>1000 mm/ann) or where there are plentiful supplies of irrigation water.

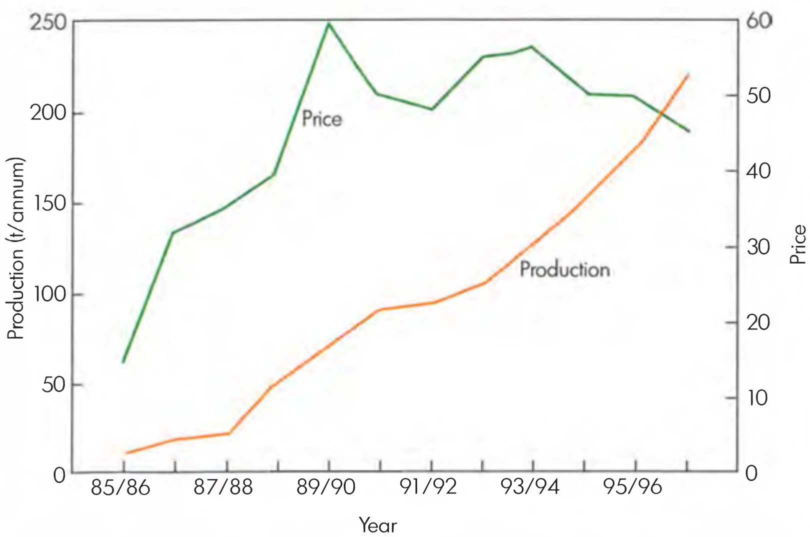
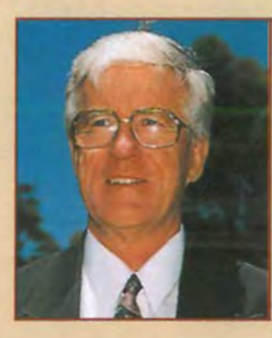


Figure 1. Changes in the annual production and farm-gate price of tea tree oil between 1985–86 and 1996–97.

About the author



John Murtagh is a principal of Agricultural Water Management Pty Ltd, a consultancy based on the north coast of New South Wales.

See *Key contacts* for address

Growth is best on medium-textured soils and since a good water supply is vital, plantations are usually sited on bottom country or alluvial flats.

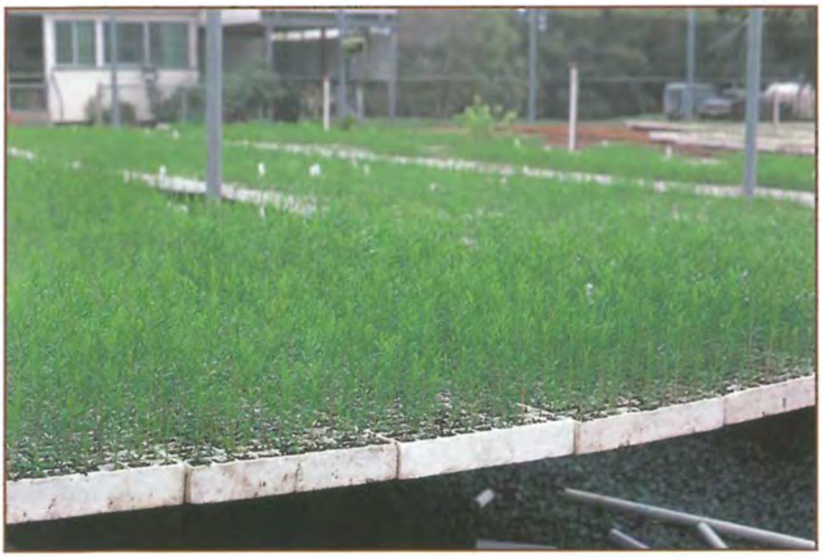
Quite apart from its effect on growth, the climate also affects the concentration of oil in leaves. The oil concentration is usually highest during summer, and least during late-winter to early-spring. This seasonal trend is more pronounced in the cooler growing regions. There is also evidence that the oil concentration can vary between, and even within days, but the reason for such fluctuations is not known.

The main production area is the north coast of New South Wales. This area was selected for the first plantations because *Melaleuca alternifolia* is native to the region and it is also home to the bush industry. Tea tree grows well on the north coast, but subsequent experience has shown that it can also be grown successfully in many other districts. Significant plantings have been made in the Mareeba–Dimbulah district of far-north Queensland where tea tree is being grown as a substitute crop for tobacco.

Varieties

To date, seed collected from bush plants has been used to establish most plantations. Whilethe mother trees are usually selected on the basis of the composition of their oil, the progeny can vary somewhat because of the strong outcrossing during pollination. Also, the growth vigour of the seedlings is unknown unless a separate and time consuming step of conducting yield trials is included before seed is sold.

The shortcomings of using bush seed are well recognised and its use is viewed as a short-term expedient. A major plant-breeding project, based at Wollongbar Agricultural Institute, is selecting improved types based on oil concentration and composition, growth and coppicing ability. The project released its first seed in 1997. Other workers have selected superior trees and are using clonal methods to propagate large numbers of plants. The latter approach provides a quicker route, albeit at a much higher cost per plant, towards using improved types in plantations, but the narrow genetic base requires careful selection and testing of the parent trees. There is every expectation that improved types will substantially outyield those used to date. In the Wollongbar breeding project, seed collected from one provenance gave plants with 3.4 times the oil yield of the mean from typical industry plants, and twice the oil from four improved selections provided by industry sources.



Tea tree seedlings at 12 weeks—a good size for planting out

Key messages

- Industry uses an Australian native plant.
- Plantations and marketing facilitated rapid expansion.
- Productivity will increase in the future.

Agronomy

Tea tree is a perennial row crop and many of the husbandry practices are similar to those used with other row crops. Being a perennial crop, a good establishment provides benefits over many years. Another important requirement is the provision of good drainage to permit access during all but the wettest periods. Timing is important for weed and insect control, and poor drainage can restrict these operations at critical times. In many instances laser levelling is used to optimise paddock drainage and facilitate flood irrigation. The design and depth of drains is especially important in areas with acid sulfate soils.

The exceptionally small seed gives weak seedlings of which only a small proportion will survive from a direct seeding into a field. Consequently, seedlings are raised in nurseries and planted out at 10–16 weeks.

Tea tree—delivering the good oil for Melaleuca Plantations of Bungawalbyn Pty Ltd

In 1987 Craig Chapman started trial plantings of tea tree on a small block in the Bungawalbyn Valley in the Northern Rivers region of NSW. Tea tree grew naturally in the area and seemed suited to the wet conditions.

It was a new industry and Craig had to field test everything from row spacings, irrigation, equipment selection, weed and pest control to harvesting techniques. Several times trees had to be ploughed in when they became overgrown with weeds. At the same time, there was concern that the markets were not well established and that tea tree oil might become a 'fad' that never developed into a viable industry.

Craig's confidence grew when he saw the success of product marketing by companies such as Thursday Plantation and he became aware of the export potential of tea tree oil.

He then purchased a larger property nearby that was suitable for flood irrigation and would offer economies of scale. For the first two years only 15 ha were planted. Craig placed great emphasis on land preparation before planting the trees. The land was initially laser levelled and planted with legume crops which were ploughed in to improve soil fertility.

Weed control was targeted as the number one priority for maintaining a healthy crop. Also, detailed crop monitoring to address problems before they got out of hand helped the company to achieve a record industry yield of 395 kg of oil/ha. This approach contrasts with expansion at all costs of the larger corporate plantations, but led to a plantation that is both high yielding and sustainable. The high yields and good oil prices also helped to finance development through oil sales.

A five-year planting program has increased the area planted to 125 ha, which can be managed by four permanent staff. A distillation facility has also been built to handle the increase in production.

During the development phase, Craig cooperated with NSW Agriculture on several research projects. The collaboration with other growers and attendance at industry field days helped expand the company's knowledge and confidence in the industry.

By 1996 the company's production of 20 t of oil was approximately 10% of Australia's total so it decided to commence its our own marketing. Craig's brother has been developing a small range of cosmetic products based on tea tree oil and wanted to launch them onto the European market. They jointly employed a marketing manager based in the U.K. to market bulk tea tree oil and value-added products.

Australia's production of tea tree oil is increasing rapidly because of large increases in the areas planted, both in NSW and Queensland. Craig is aware that at some stage in the next few years the growth in oil supply may outstrip the growth in demand.

To maintain the long-term viability of their plantations and to keep the industry within Australia, Craig believes that all growers should be focusing on increasing yields and production efficiencies through technological improvement.

Tea tree rows at approximately 6 weeks after planting

Large numbers, up to 40,000/ha, are transplanted. The first two months after transplanting is a critical phase for the plantation since the seedlings have a poor competitive ability and the survival and vigour of adult plants is dependent on good husbandry during this phase. The two most important factors are weed control and provision of adequate water. Weed control remains important issue even in established plantations.

The nutritional requirements of tea tree are not well understood. Each harvest removes a large quantity of biomass and some return of nutrients is essential for long-term productivity. Nevertheless, a number of trials have given small or no response to conventional fertilisers, possibly because the tea trees tap into soil nutrients below the rooting depth of previous crops. If so, the lack of a fertiliser response should be viewed as a short-term condition. There are some indications that tea tree requires a slow, steady supply of nutrients as can be obtained from organically bound nutrients.

On the north coast of New South Wales, a crop is ready for the first harvest 18–24 months after planting. Thereafter it can be harvested every 12 months. Oil concentrations are generally highest in late-summer, but regrowth tends to be best after a spring harvest. In one experiment, these two effects balanced out between different harvest times and there was no consistent effect of month of harvest on the oil yield.

In the warmer environment of north Queensland, the harvest interval is 8–9 months. The different interval between the two areas reflects the 3–4 month period of winter dormancy in New South Wales and the absence of a dormant period in Queensland. This suggests that the growth rate during the growing season is similar at both locations.

The crop is harvested by cutting the stems near ground level, chopping the biomass with a heavy duty forage harvester, and feeding the chopped material into a transport bin. The bin can also be designed to act as the distillation vessel. Steam distillation is used to extract the oil from the biomass and, after the vapours are condensed, a flotation procedure is used to separate the oil from condensed steam.

A plantation will require the normal machinery that is used for row cropping, together with specialised harvesting and distillation equipment. Small producers can pool their resources and use a single distillation unit. In some districts, harvesting and distillation can be done under contract.

The oil yield reflects both the oil concentration and biomass yield. With current knowledge and using bush seed, the target oil yield from a plantation should be in the 170–220 kg/ha range. This is slightly higher than the 150–200 kg/ha range published earlier and reflects the increased management skills in the industry. Yields from the new selections should be higher but yield trials are required to quantify the amount. The above yields relate to a single harvest and they tend to be similar in all regions. However, where the harvest interval is shorter as in north Queensland, the oil yield per annum will be greater.

Pest and disease control

Tea trees can be damaged by a number of insect species. Most damage is done to young growth and the plant generally recovers by reshooting from dormant buds. Thus, the insect problem is one of reduced growth rather than the death of plants. The most important insect pests are pyrgo beetle (*Paropsisterna tigrina*), a psyllid which forms pits on the leaf, and a gall forming fly (*Dasineura* sp.).

Sometimes the impact of these pests can be reduced by beneficial insects. Hence, an integrated pest management program should be adopted. Some insecticides are registered for use on tea tree.They were selected for lack or persistence and hence low risk of remaining in plants and contaminating oil.

There are no known serious diseases of tea trees.

Tea tree oil processing plant at Coraki

Postharvest treatment

The oil has a long shelf life and can be stored to suit market considerations. Issues to address are the use of clean inert containers that are sealed to prevent the diffusion of water vapour, and storing under nitrogen to reduce the formation of oxidation products. The containers are commonly of stainless steel and there is an increasing trend to use stainless steel throughout the distillation pathways.

A gas chromatograph analysis is used to define the chemical composition of the oil, and some merchants require a chemical profile with each batch. There are various registered laboratories able to undertake this analysis.

Harvesting a tea tree crop

Economics of production

Tea tree oil is a high return crop. It is expensive to establish but the perennial habit and high value of the oil can give high profits. Establishment costs, including equipment purchase or lease but excluding the cost of land, are about $7000 to $9000/ha. Subsequent maintenance costs approximate to $2500–$3500/ha.

The economic return is very sensitive to the yield and price of oil, as is illustrated for a large plantation in Table 1.

Table 1. The effect of yield and price of oil on the return (%) on capital

Oil yield (kg/ha/ann)	Oil price ($/kg)			
	20	30	40	50
100	-8	1	6	13
150	-1	9	20	30
200	6	20	33	47

Source: T.L. Reilly 1991. Reports: Tea Tree Marketing & Planning Conference, Ballina.

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Fruits

Durian

T. K. Lim

Introduction

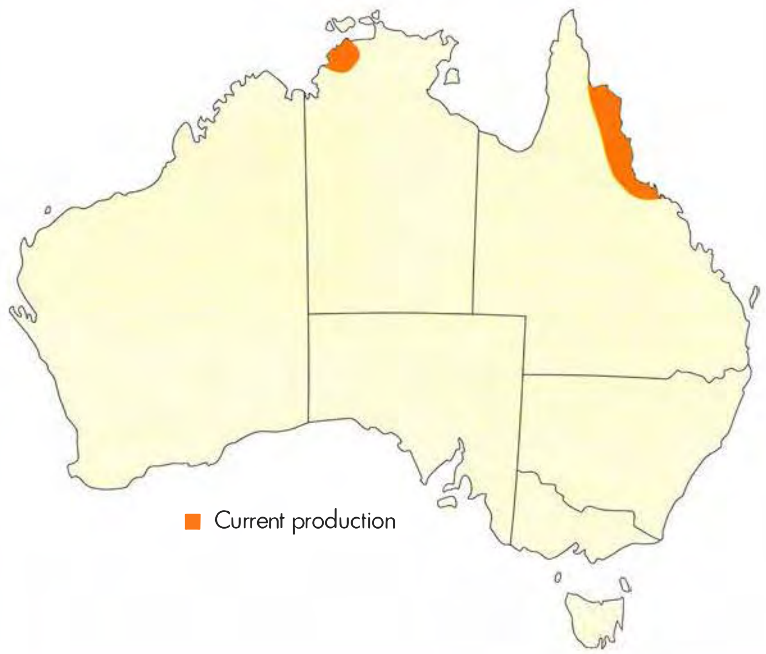
Durian (*Durio zibethinus* Murr.), hailed as the 'king of fruits' is highly esteemed by most Asians for its exquisite aroma and flavour, but rebuffed by most Europeans because of a strong odour viewed as offensive and pungent. It is the most lucrative fruit grown in Southeast Asia. Based on a production of 1.5 million tonnes in the producing countries and a conservative farm gate price of US$1000/t (Table 1), the value of the industry world wide is estimated to be US$1.5 billion.

The leading producers of durian in the world are, in decreasing order, Thailand, Malaysia and Indonesia (Table 2). Thailand exports about 5.5% of its total production as fresh and frozen fruit to Hong Kong, Malaysia, Singapore, Taiwan, Europe, Brunei, USA (mainly frozen), Canada (mainly frozen), Australia (frozen) and Japan (frozen). In 1994, Thailand's durian exports to Taiwan boosted its export returns from this commodity to over US$20 million, indicating huge market potential in mainland China. Over the past 10 years, the area planted to durian has almost doubled, from 58,000 to 112,000 hectares (Table 3).

Since April 1996, 81 consignments totalling over 515 t of frozen durian were imported into Australia from Thailand mainly through Sydney and Melbourne, and to a lesser extent through Brisbane, Adelaide and Perth (Williams, AQIS, 1997, per. comm.).

In Australia, the durian industry is at an embryonic stage. Since the introduction of clonal material in 1975, orchard plantings started only in 1980 in north Queensland, and in the Northern Territory in 1984. In north Queensland, plantings are found along the coastal strip from Tully (18°S) to Cape Tribulation (16°S). There are 27 growers with around 4000 trees, a quarter of which are fruiting. In the Northern Territory, 1000 trees are planted around Darwin (12.5°S), spread among 14 growers. Some 400 of these trees are bearing. The vast majority of growers are Europeans who have developed a penchant for durian.

The industry has a number of strengths. A gene-pool of world renowned cultivars has been introduced. These cultivars are being multiplied. The durian fruit is not a host of the dreaded papaya fruit fly, and there are no durian fruit borers. There are strong market opportunities for this high-priced fruit in both domestic and international markets, particularly in the off-season for other growing regions



(Table 4). Most orchards are suited to mechanisation, enabling cost-effective farm management. The fruit has a diversity of value-added products. Some constraints to further development of the industry are: (a) there is no recommended variety list; (b) erroneous identification of cultivars; (c) choice planting material is scarce; (d) threat of fruit-spotting bugs and diseases caused by *Phytophthora*; (e) the long juvenile period before returns can be realised; and (f) the absence of an industry levy to fund research and development.

Markets and marketing issues

No accurate estimates of the present Australian production or sales are available because of the meagre size of the industry. However, based on prices of \$8–12/kg for fresh fruits and \$15–20/kg for arils in punnets received by growers in Queensland and the Northern Territory, the potential of the industry is bright. Assuming an orchard with 100 trees/ha having an average yield of 50 fruits/tree at year 10, and a farm price of \$10/kg with an average fruit weighing 2 kg, the potential annual return of an industry growing 5000 trees is \$5 million. In Thailand and Malaysia average yields reported are around 10–18 t/ha with 50 fruits/tree and each fruit weighing 1.5–4 kg.

The main consumer demand comes from the ethnic Asian population, especially from Southeast Asia and Hong Kong. Watson reports that the domestic market (1988) can absorb production from 100 ha. Most consumers prefer fresh fruit, but frozen products are also acceptable. Recently, Japan started importing durian from Malaysia and Thailand in the form of excised arils in sealed polythene punnets. This form of packaging alleviates the strong odour, keeps produce fresh, and poses no problems with airline transportation.

The export potential for durian is good, as production in northern Australia can fill the market window from January to April: late December to early February in the Northern Territory, and February to April in north Queensland (Table 4). Thailand's durian season culminates in April–July, Malaysia's main season straddles June–August, with a minor crop in November–December, and Indonesia's crop occurs from October to December.

Table 1. Prices paid for durian fruit.

Country	Price (US\$)
Malaysia[a]	5.50- 6.60
Singapore	
- named varieties[b]	10.00–14.00
- common village types	3.00–6.00
Thailand[b]	3.00–4.50
Indonesia[a]	0.25–5.00
Philippines[a]	3.00–4.50
(Metro Manila)	6.00–20.00
Australia[b]	6.40–9.60

[a] Retail price/fruit (source: Alim et al. 1994)
[b] Wholesale price/kg (source: Lim 1995)

Table 2. Durian production (t) in the major producing countries, 1988–1992.

Country	1988	1989	1990	1991	1992
Indonesia	193,200	139,193	242,585	205,389	152,501
Malaysia	289,500	319,700	353,100	389,900	384,500
Thailand	444,145	468,645	464,959	539,190	720,607

Source: Nanthachai (1994)

Table 3. Durian statistics in Thailand.[a]

Year	Total area ha	Total yield (t)	Average farm price US\$/kg	Total fresh export (t)	Export value US\$m
1983	57975	308475	1.16	2819	2.58
1994	111921	767415	0.77	26915	20.9[b]

[a] Main importers: Taiwan, 13,092 t (US\$12.08m); Hong Kong, 8105 t (US\$4.75m)
[b] Siriphanich (1996)

About the author

T. K. Lim is Principal Horticulturist with the Northern Territory's Department of Primary Industry and Fisheries (see *Key contacts* for address). He has degrees in agricultural science from the University of Malaya and holds a PhD from the University of Hawaii. His current area of interest is focused on tropical fruits and Asian vegetables.

The durian is a highly prized fruit in South-East Asia.

Most of the major producing countries are situated in Southeast Asia and have their production peaks around the middle of the year (Table 4). There may be slight variation of the fruiting period from year to year depending on the weather, giving rise to off-season fruiting. Malaysia and Indonesia have two fruiting seasons because durian is grown in various localities. The main season in Sarawak and Sabah, East Malaysia straddles June through August and both have a small season in November–December. Neither state exports its crop as the fruit are mainly consumed locally. The main harvest in Indonesia is from October to February, but Sumatra produces a crop around June–September.

In Thailand, locality and cultivar also influence the length the fruit production period. The cultivar 'Kradumtong' provide fruit early in the season. The eastern provinces produce fruit from mid April to June–July, the southern in July–September and the northern provinces during June–July. In northern Australia, as represented by north Queensland and the Northern Territory, durian crops are produced at the end and beginning of the year, mainly for the domestic market. In the Northern Territory, the fruiting period usually occurs from November to the end of January (in some years as early as October and in others as late as early February) and in north Queensland, ie. from Tully to Cape Tribulation, from late January to the end of April).

Key message

Durian—the golden egg investment

Production requirements

Durian is indigenous to the hot equatorial rainforest of Malaysia and Indonesia. It thrives in a hot (mean minimum 22°C mean maximum 33°C) humid tropical environment with high rainfall of 2000–3000 mm evenly distrib-uted throughout the year, and with good cloud cover. In this respect, the crop performs better in the tropical environment of north Queensland than in the Northern Territory. The para-mount environmental constraints are relative humidity and the duration of the absolute minimum temperature. Prolonged low winter temperatures in northern Australia, coupled with the low relative humidity (< 40%), can cause defoliation and abortion of flowers. Trees that lose their leaves may succumb to dieback from sun-scorching of the exposed branches. All the growing areas in northern Australia are at risk of severe cyclonic damage.

In its native habitat, durian thrives on well-drained, deep, fertile, loamy soil, rich in nutrients and organic matter. In north Queensland, most durian trees are grown on marginal lands previously used for sugarcane production. These soils have a pH as low as 4, and are depleted of major and minor nutrients and organic matter. In the Northern Territory, durian are grown on sandy soils, poor in nutrients and organic matter, and extremely poor in water-holding capacity. Large quantities of fertilisers are needed in both cases and irrigation is critical for durian in the Northern Territory.

Varieties

All the clones currently found in Australia have been introduced from Southeast Asia, in the main by growers themselves and to a lesser extent by the Department of Primary Industry in Queensland and Department of Primary Industry and Fisheries in the Northern Territory. Only a dozen or so have been evaluated at bearing age and have planting material available. Most are being evaluated for adaptability and productivity, which is a slow process because of the long gestation period. The following are attributes of a good cultivar: (a) good aril recovery, 30% or more; (b) yellow to deep yellow, firm, creamy aril; (c) small seed; (d) high and consistent yielder, 70–100 fruits/tree; and (e) resistance to major pests and diseases. Thus far, about 40 clones have been introduced into Australia, including eight *Durio* species, as follows.

From Malaysia: Ampung, Capri (MDUR 59), Chin, D 2 TE, D 2 SJRS, D 7, D10, D 16, D 24 Ng, D 24 Siah, D 24 CYK, D 96, D 99 TE, D 99 (Gob Siah), D 118 (Tembaga), D 120 (KK5 Manong), D 123 (Chanee), D 140, D 143, D 144, D 145, D 160, D 163 (Hor Lor), D 164 (Red Flesh), D168, D 175 (Red Prawn), D 178 (P 88), D 179 (P 99), D 186 (Nasi Kunyit), D 188 (MDUR 78), D 190 (MDUR 88), Eden 5, Hew 1, Hew 2, Hew 3, Hew 4, Hew 5, Hew 6, Hew 7, Hew 9, KK 11, P 21, P 601, P 604, Permasuri, Sahom, TLK/YEAO, Taiping 1, XA

From Indonesia: Hepe, Petruk, Sitokong, Sukun, Sunan

From Thailand: Chanee, Chompoosri, GaanYaow, Gob, Gob Yaow, Kradumtong, Gumpun, Kampun-Luang Monthong DPI, Monthong TE, Luang

From Thailand via Hawaii: Pomoho Monthong

Local Australian selections:- Johnson, Limberlost, Z 1, Diedre 1, Diedre 2

Table 4. Production periods (shaded sections) in durian growing areas.

Production Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
W. Malaysia	□□	□□	□□	□□	□■	■■	■■	■□	□□	□□	■■	■□
E. Malaysia	□□	□□	□□	□□	□□	■■	■■	■□	□□	□□	□■	■■
Thailand	□□	□□	□□	□■	■■	■■	■■	■■	■□	□□	□□	□□
Indonesia	■■	■□	□□	□□	□□	■■	■■	■■	■□	■■	■■	■■
Vietnam	□□	□□	□□	□□	■■	■■	■■	□□	□□	□□	□□	□□
Laos	□□	□□	□□	□□	□■	■■	■■	□□	□□	□□	□□	□□
Kampuchea	□□	□□	□□	□□	□■	■■	■■	□□	□□	□□	□□	□□
Philippines	□□	□□	□□	□□	□□	□□	□□	□■	■■	■■	■□	□□
Brunei	□□	□□	□□	□□	□□	□□	■■	□□	□□	□□	□□	□□
Burma	□□	□□	□□	□□	□□	■■	■■	□□	□□	□□	□□	□□
Singapore	■□	□□	□□	□□	■■	■■	■□	□□	□□	□□	□□	■■
North Queensland	□■	■■	■■	■■	□□	□□	□□	□□	□□	□□	□□	□□
Northern Territory	■■	■□	□□	□□	□□	□□	□□	□□	□□	□□	■■	■■

Source: Lim (1996)

Durio species besides *Durio zibethinus: Durio dulcis* (Lahong) *Durio graveolens* (Durian merah), *Durio kutejensis* (Lai), *Durio oblongus, Durio oxleyanus* (Isu), *Durio micrantha, Durio testudinarum* (Durian kura)

Agronomy

Some clonal self-incompatibility has been reported in durian. Our studies showed that selfing can result in more premature fruit abortion and the production of deformed fruit, thus outcrossing is recommended for durian. It would be advisable to have a mixed clonal stand with different clones in separate rows rather than a pure stand. A mixed planting of early, late and medium flowering clones will also extend and enhance productivity.

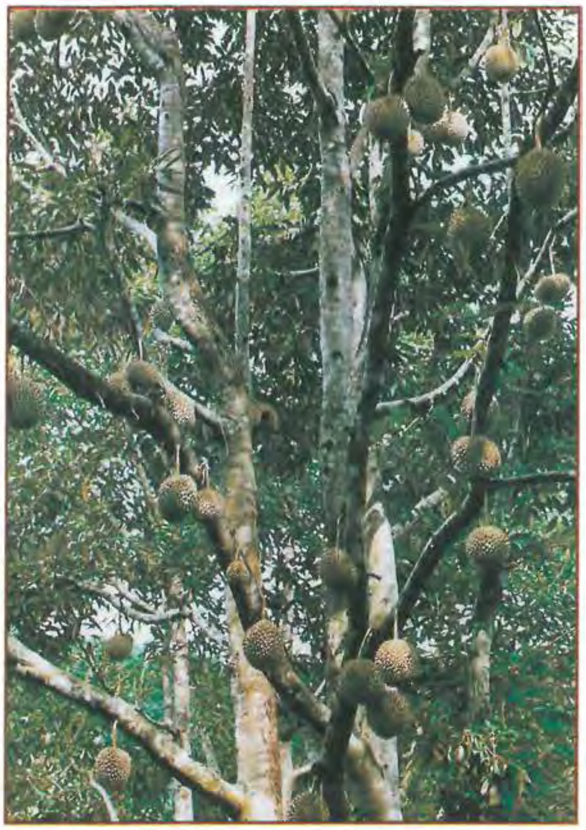
The planting distance commonly employed in northern Australia is 10–12 × 10–12 m square or triangular planting system, although a distance of 10 × 8 m is also practised in the Northern Territory. A permanent natural windbreak needs to be in place before crop establishment because of the strong winds experienced in the growing areas. Durian requires some light shading (dried palm fronds or synthetic fabric) during the first two years after field establishment, especially around Darwin. Owing to the threat of *Phytophthora* diseases, trees should be planted on raised mounds especially in low-lying areas.

Young trees 2–4 years old should be pruned of orthotropic and criss-cross plagiotropic branches to open up the canopy. On mature bearing trees no pruning is carried out. Under Darwin conditions it takes around 110–130 days from anthesis to harvest maturity.

Water shortage poses no constraint to the cultivation of durian in north Queensland which has a wet tropical climate similar to the crop's native habitat. However, in the monsoonal/tropical environment of the Top End of the N.T., water shortage can play a critical role. Durian is extremely sensitive to drought stress, at all stages of growth, from the seedling to the mature, bearing stage, and there is variation among varieties to drought susceptibility. Durian is a shallow-rooted crop with 60% of the total root length confined within 60 cm from the crown and 0–30 cm from the soil surface. In the Northern Territory, the tentative recommendation is to apply water at rates of up to 2000 L/tree/week for trees with 4 m canopy spread during September to November and lower rates during other months. Mulching trees can also help to conserve soil moisture.

Fertiliser application should be scheduled in accordance with the crop phenology and fluctuations in crop nutrient requirements. Diagnosis of crop nutrient demand should be assessed from leaf and soil sampling done in November in Darwin, and using the tentative standards drawn up for northern Australia. For instance, studies showed most NPK fertilisers should be applied immediately after crop harvest just at the incipient stages of major vegetative flushing, another smaller application a month or two before flowering and around early stages of fruit development. The quantity of fertilisers used should be adjusted yearly according to the results of leaf sampling as and the crop load (yield) removed. Application of micronutrients as foliar spray should be done during early vegetative flushing.

The durian fruit is produced along the branches of the tree.



A large mature durian tree in full fruit

Pests and diseases

The most serious pest of durian in Queensland and the NT is the fruit-spotting bug, *Amblypelta lutescens*, which damages flowers and developing fruits at all stages. In the Northern Territory, green ants (*Oecophylla smaragdina*) and mealy bugs deform and dry up flower buds and deform developing fruits, while meat ants, *Iridomyrmex* sp., devour flowers and a longicorn borer attacks the bark. Minor insect pests include *Rhyparida* beetles damaging young foliage, thrips, and mites on developing fruits.

Disease caused by *Phytophthora palmivora* have been encountered in north Queensland and the NT. This is by far the most serious disease attacking durian at all stages of the crop growth. It causes seedling dieback, root rot, patch canker on the trunk, leaf rots and pre and post-harvest fruit rots. Also, dieback caused by a suspected basidiomycetous fungus was encountered in the NT, resulting in dieback of tree with different symptoms to that caused by the ubiquitous *P. palmivora*. Another tree decline of unknown aetiology was also observed in north Queensland. In the Northern Territory, stem lesions around wounds have been associated with a *Phomopsis* and *Lasiodiplodia theobromae* (G. Johnson, CSIRO, Brisbane, pers. comm.). A minor disease observed is leaf spot caused by the alga, *Cephaleuros virescens*.

Harvesting and postharvest handling

Most growers picked ripe fruits when they dropped from the tree. Such fruits have a very short shelf live of 2–3 days. To reduce fruit damage caused by the fall, tarpaulins or nets can be erected below the tree during the ripening months. The shelf life of intact fallen ripe fruits can be extended by 1–2 or more days if they are stored at 5–10°C.

Selective harvest before the fruit is ripe, as is practised in Thailand, will extend the shelf life, but this needs a great deal of skill and experience. Thai growers use a combination of harvesting indices in selective harvesting. These include: the number of days from full bloom; colour, elasticity and disposition of the spines; intensity of the odour emitted; the sound heard when the fingertips are run through the furrows between the spines; changes in fruit stalks and water flotation tests (Subhadrabandhu et al., 1991). Selectively harvested fruit should be stored at 15°C which will extend their shelf life to 3 weeks, and quick-frozen arils retain their flavour for more than 3 months.

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Lychee and longan

Chris Menzel
Cameron McConchie

Introduction

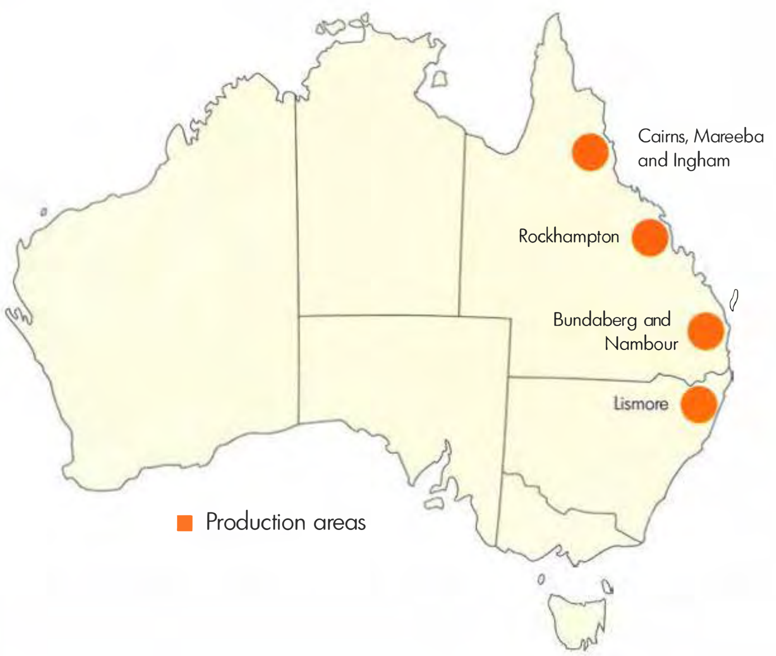
The lychee (*Litchi chinensis* Sonn.) and longan (*Dimocarpus longan* Lour.) are members of the Sapindaceae family to which the popular rambutan (*Nephelium lappaceum* L.) also belongs. All produce delicious fruit on evergreen trees that will eventually grow to heights of more than 20m. Lychee and longan are subtropical, although some cultivars will crop at higher altitudes in the tropics. The largest producers of lychee and longan are China, Thailand and Taiwan. Lychees are also important in India and Vietnam. Further expansion is occurring in these countries to meet demand generated by the increasing regional affluence.

Although lychee and longan were introduced into Australia more than 60 years ago, major commercial plantings commenced only in the 1970s. Currently, there are about 450 growers of lychee with an annual production of 3000 t worth $15m. Production has steadily increased over the past eight years (see Figure 1). Longan production is considerably smaller with a value of about $2m, but is also rising, especially as new plantings in northern Queensland begin to bear fruit.

Both crops are difficult to grow and yield consistently. The major production problems with lychee are irregular flowering and poor fruit retention, while in longan, alternate bearing and small fruit size reduce grower returns. Trees take three to five years to come into production, and will not yield substantial crops until year six or eight. They require regular chemical control measures for pests, and suffer heavy losses to birds and fruit bats if not netted. The fruit ripen only on the tree and have a very short self life without refrigeration.

Successful lychee and longan production requires an experienced horticultural manager able to deal with irrigation, tree nutrition and a considerable pest load. Efficient packing and cool room facilities are needed as both crops deteriorate very quickly after harvest.

Australia has an advantage in the international market because it produces fruit during the northern hemisphere 'off season' including the lucrative Christmas and Chinese New Year festivities. Demand for high quality product far exceeds Australia's ability to supply. There are also opportunities in the domestic market, although some promotion and retail/ consumer education are required.



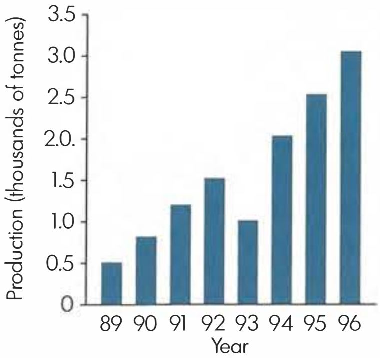


Figure 1. Trend in lychee production in Australia.

Markets and marketing issues

There are approximately 500,000 t of lychee and 300,000 t of longans produced in Asia. Total production of lychee in the southern hemisphere is around 50,000 t, while longan production is almost negligible.

In South East Asia, about 100,000 t of longan and 25,000 t of lychee are traded as fresh fruit during the northern season. Longans are the most important of Thailand's fruit exports, with trade in the lucrative fresh fruit dominating, but with fruit also sold for canning or drying. The total value of this commerce is at least $50m. Trade is important and expanding in China, Taiwan and Vietnam, and about 15,000 t of lychee is exported to Europe from Madagascar and South Africa.

In Thailand during the northern summer, early longans may fetch from $3 to $5/kg, but as supplies increase, the price drops to below $1/kg. Returns for lychee are generally at least double those for longan. Out-of-season fruit from Australia during the northern winter would not necessarily achieve the higher returns.

About the authors

Dr Christopher Menzel is Senior Principal Horticulturist at the Queensland Department of Primary Industries in Nambour in southern Queensland. Dr Menzel has worked on cultivar development, agronomy and physiology of lychee for the past 15 years, and has extensive international experience in this crop. He has written many articles and reviews on lychee including several book chapters.

Dr Cameron McConchie is Principal Research Scientist with the CSIRO Division of Plant Industry at St Lucia in Brisbane. Dr McConchie has studied the breeding system of lychees for the past 10 years.

See *Key contacts* for the authors' addresses.

The bulk of Australia's lychee production is sold locally, either at the farm gate or through the central markets, with about 30% exported. Exports have risen sharply in the past few years with improvements in postharvest handling, and the development of co-operative marketing groups and quality assurance programs. These groups export about 60% of their production.

The main markets are Hong Kong, Singapore, French Polynesia, the United Arab Emirates and the United Kingdom. Average net returns to the growers are about $5.50/kg. This is after taking the costs of freight, commissions and agent's fees etc. At this stage the lucrative markets of Japan and the United States are not available because of quarantine restrictions associated with lychee being considered a host of fruit fly.

There have been trial consignments of longan fruit from northern Queensland to Hong Kong, but outturns have sometimes been disappointing. It can be concluded from these studies, that further research on storage temperatures, packaging, etc. is required if growers are to fully exploit this market. Average net returns to the growers were about $4.50/kg, after taking into account freight, commissions and the extra costs of plastic crates.

Production requirements

About 50% of lychee production is in northern Queensland (Cairns, Ingham and the Atherton Tablelands), 40% in central and southern Queensland (Rockhampton, Bundaberg, Gympie, Nambour and Caboolture) and only 10% in northern New South Wales. Longans are mainly found on the Atherton Tableland, with smaller plantings on the coast as far south as Byron Bay in northern New South Wales (see map).

The lychee season lasts from about early November in northern Queensland to about March in northern New South Wales. Longan generally matures about two months later.

Trees perform best on well-drained clay loam soils of medium to high fertility, with a minimum of 1 m of well-drained topsoil. Trees may die on heavy clay soils that become waterlogged. There can also be problems on very sandy soils during hot weather in northern Queensland. Slopes greater than 15% are best avoided as they will not allow safe use of machinery for pest control, tree management, and harvesting, and may erode.

Lychee requires a period of cool weather (15–20°C) for successful flower initiation, but may be killed by frosts. Hot dry weather after fruit set has also been implicated in fruit drop, browning and splitting. Fruit under these conditions do not develop full red colour. Trees are also susceptible to wind damage, and should be protected by wind breaks.

Irrigation is normally required to produce commercial crops, but care must be taken with water quality. Water with an electrical conductivity of more than 600–1000 microsiemens/centimetre or dissolved salts of more than 500 parts per million may reduce productivity in lychee. It is generally considered that about 2–4 ML of stored water is required for each hectare of trees.

One person should be able to handle about 5–7 ha of mature trees without the need for other staff except during harvesting and packing. Depending on the yield and spread of cultivars, up to 5–10 staff would be required for harvesting over summer. Basic equipment required would include: an under-tree sprinkler irrigation system, tractor, sprayer, slasher or mower, trailer, harvesting equipment, netting and a packing shed and cold room.

Key statistics

	Lychee	Longan
Total area (ha)	1800	130
Total production (t)	3000	450
Number of growers	450	45
Exports (t)	800	40

Lychee cv Wai Chee

Longan cv Haew

A local horticulturist should be consulted about the growing and marketing of these crops before orders are placed for nursery plants. There is also valuable information in the *Proceedings of the Lychee Seminar* published every three to four years and in the Australian Lychee Growers' Association newsletter *Living Lychee.*

Cultivars

There are over 40 cultivars of lychee and 20 for longan in Australia. However, the development of the industry has been hindered by lack of performance data for the major production regions. This has been accentuated by difficulties in identifying cultivars. Highest prices are paid for early and late fruit with strong skin colour, firm flesh, aromatic flavour, a high proportion of edible flesh and small seed.

Lychee cultivars currently being planted in northern Queensland on the Atherton Tablelands and coast include 'Kwai May Pink' ('Bosworth Number Three'), 'Fay Zee Siu' and 'Souey Tung', the latter two being quite early. 'Kwai Mai Pink' is also popular in central and southern Queensland and in northern New South Wales, along with 'Salathiel', and the late cultivar 'Wai Chee'.

The longan cultivars exploited are predominantly from Thailand and include 'Chompoo', 'Haew' and 'Biew Kiew'. The Hawaiian selection 'Kohala' is also being planted because of its earliness and large fruit, but it loses flavour under some circumstances. 'Biew Kiew' is very late and may not mature before winter in northern New South Wales. Plants are available from commercial nurseries, but must be ordered at least 6 months in advance.

Agronomy

A well-managed orchard should have a long commercial life. Hence, close attention to orchard layout and land preparation will bring rewards for many years. Decisions need to be made on row direction, spacings, placement of waterways and drains, mounding, wind protection and all weather access to the block. The local horticulturist should be able to help with the layout of the orchard and care of young trees. There are also details in the Queensland Department of Primary Industries 'Lychee Information Kit'.

Key messages

- Exotic fruit adapted to warm subtropical coastal areas and the elevated tropics
- Strong potential for exports to South-East Asia and Europe
- About $150,000 required to set up a viable 7 ha farm
- Concentrated harvest over summer
- Strong commitment to quality and group marketing required by growers

Plantings generally range from 100–300 trees/ha. Recommended spacings are 12 m × 6 m for spreading cultivars such as 'Fay Zee Siu' and 'Souey Tung' (equivalent to 140 trees/ha), and 6 m × 6 m for upright or low vigour cultivars such as 'Kwai May Pink', 'Salathiel' and 'Wai Chee' (equivalent to 280 trees/ ha). In other countries, higher density plantings have given greater returns, but these types of orchards are only experimental in Australia. There is little information available for longan, although the data for lychee could be used as a guide.

Tree rows are usually considered to best run north–south, but erosion and operator safety should be considered. Strong winds can seriously affect tree growth and production, so windbreaks need to be considered in most localities.

A soil analysis (including soil pH) before planting will indicate any potential nutrient deficiencies or imbalances which can be corrected. Discuss these results with your local horticulturist. Some soils may need an application of lime, phosphorus, nitrogen and some organic matter into the planting site. Many growers sow a manure or cover crop before planting trees and incorporate this organic matter into the soil to improve soil texture, fertility and orchard establishment.

Irrigation is generally considered essential for regular production in most of the commercial growing areas of eastern Australia, and is normally provided by under tree sprinklers. These systems can also be used to fertigate trees. In dry areas, the young plants will probably require watering at least weekly until they are well established.

Experiments have shown that drought has impacts on leaf growth, flowering, fruit development and quality in lychee, and longan would probably respond similarly. However, in deep, moisture-retentive soils, it can take several weeks before drought has any impact on production.

Fertiliser management in lychee is currently based on the results of leaf and soil analyses collected annually in winter. During the early life of the orchard, before the trees start to crop, it is recommended that the trees be fertilised about every three months. You will need to gradually increase the amount of fertiliser as the trees become larger.

Timing of fertiliser application generally has little impact on production. Most nutrients can be applied in two or three applications between flowering and harvest. The most likely nutrients to be low or deficient are nitrogen (N), potassium (K), magnesium (Mg), zinc (Zn), iron (Fe) and boron (B). In contrast, many orchards in Australia have excess amounts of phosphorus (P). There is little information available for longan, but following recommendations for lychee would be a good starting point. Information on the types of fertilisers to use can be obtained from your local produce agent.

Pest and disease control

Lychee and longan are subject to a wide range of pests which attack the tree, flowers and fruit. However, only a few of the regular pests affect production and need to be controlled. Your local entomologist will help you identify the major pests in your area. There are also consultants who can monitor pests in your orchard, advise on a spray program and help calibrate your sprayer.

Erinose mite (*Aceria litchi*) is a major pest of lychee and causes a brown, felt-like growth on the developing leaves, flowers and fruit. It can be very difficult to eradicate once established in an orchard. Recommended control is with three sprays of dimethoate or wettable sulfur at 2–3 week intervals to coincide with the elongation and expansion of new leaf flushes. New air-layers should be treated before they are planted.

Marketing group checking fruit quality of lychee

Macadamia nutborer attacks both lychee and longan every season, and can devastate the crops. Larvae develop mainly in green fruit with significant seed development, but before there is a large amount of flesh. Sprays of azinphos-methyl need to be applied to coincide with the hatching of the oldest 10% of the eggs so that the newly emerged larvae will be killed before they enter the skin of the fruit. Effective control will probably require a minimum of 2–3 sprays.

Flower caterpillars (*Lobesia* spp., *Isotenes miserana*, *Prosotas* spp. and *Phycita leucomiltra*) are major but occasional pests of lychee, which can be readily controlled with endosulfan or carbaryl. Trees should be sprayed before the flowers open.

Both the fruitspotting bug (*Amblypelta nitida*) and the banana spotting bug (*A. lutescens*) are common in southern districts. The banana spotting bug is common in central and northern Queensland. These bugs cause the developing green fruit to drop. Generally, lychees are less susceptible once the fruit have started to colour, whereas longans can be attacked right up to harvest. Two sprays of endosulfan starting two weeks after fruit set will generally provide adequate control.

Adult fruit piercing moths (*Othreis fullonia* and *Eudocima salaminia*) cause much damage to lychee and longan by piercing the skin of ripening fruit and sucking out the juice. No chemical control is available for these large nocturnal moths, although nets with a mesh of 15 to 20 mm will exclude them. These nets will also exclude birds and flying foxes. A smaller mesh with a cross hair would also keep out some macadamia nutborer and elephant beetles. These cost $15,000–25,000/ha. Check with netting suppliers in your area.

Harvest, handling and postharvest treatments

For lychee, the season commences with cultivars 'Fay Zee Siu' in northern Queensland in November and finishes with cultivar 'Wai Chee' in northern New South Wales in March. For longan, fruit are available from late January (cultivar 'Kohala') until early April (cultivar 'Haew') in the same regions. At any one location, harvesting normally lasts about six weeks with a spread of cultivars.

Neither lychee nor longan will ripen off the tree, so they must be picked mature. For lychee, maturity is indicated by a minimum brix:acid ratio of 35:1, although ripe fruit generally have a much higher ratio. Maturity of lychee is judged by the shape, size, colour and flavour of the fruit, which varies greatly with cultivar. Normally, longan fruit can be judged by fruit size and flavour. Both crops become bland if picked over-mature.

Fruit should be harvested early in the morning before they warm up. Some growers pick early season fruit individually off the panicle (spot-picking), but generally the bulk of the crop is picked in clusters. There is strong demand for longans on branches and branchlets in some markets.

Once lychees are picked, they start to dry out and brown. Fruit should be kept in a high humidity and cooled to 5°C as quickly as possible. Hydrocoolers or cool rooms are frequently used for this purpose. Untreated longan fruit suffer chilling injury and lose flavour below 9°C, but do not brown as quickly as lychee.

A heavy crop of longan

After picking, fruit are destalked and sorted visually on mechanical conveyors to remove small, poorly coloured or damaged specimens.

Industry quality standards have been developed for lychees, but none is available for longan. For lychee, 'Extra class' must be practically free of defects, and typically comprises no more than 10% of the crop. 'First class' fruit can have moderate defects, with skin blemishes not exceeding 60 mm^2 in total on any one fruit. Other standards operate for other segments of the industry which have a commitment to quality assurance and are members of the United Lychee Marketing Association (ULMA).

To reduce water loss and browning, lychee fruit are marketed in bulk or in crispywrap bags in 9 L cartons which hold 5 kg of fruit packed in two 2.5 kg low density polybags. Fruit can also be packed in 250 g punnets, with a cling wrap film. Longans are generally marketed in bulk packages, including non-recyclable plastic crates. Both fruit should be free of surface moisture before being packed to reduce the potential for disease development.

Fruit are normally shipped by refrigerated transport. This system retains the red skin colour in lychee and greatly prolongs shelf life in both crops. However, once the retailers open the bulk packs, fruit begin to deteriorate under air conditioning in the stores.

In Thailand, longan fruit (on branchlets) are treated with sulfur dioxide, packed in 10 kg plastic crates, cooled to 2–5°C, and cool transported to Bangkok for sea or air freight to Hong Kong, Singapore and Indonesia where they have a shelf life of up to six weeks. In Australia, there is temporary board approval of this treatment, which substantially reduces the incidence of the postharvest rots and off-flavours that may develop in cool storage.

Fruit are sold at the farm gate, consigned to the wholesale markets in Brisbane, Sydney or Melbourne, or exported. You can handle marketing yourself or join one of the lychee marketing groups. If sending fruit to some of the southern markets quarantine restrictions must be adhered to. These restrictions vary from season to season.

Economics of production

At least $150,000 is needed to set up a viable 7 ha lychee farm. This will cover basics such as purchase of a tractor, sprayer, slasher, small farm shed, and irrigation system, and tree establishment. It does not include the cost of land. A further $150,000 would be required for netting, picking and packing (including a cold room) once the trees started to bear. It would cost about the same to set up an equivalent longan enterprise.

Yields vary widely with cultivar, season and location, from about 10 to 100 kg/tree at year ten. Average yields would be expected to be about 5 kg/tree at year five rising to about 50 kg/tree at year ten. Longans are slightly more productive, especially on the Atherton Tableland in northern Queensland.

Prices also vary greatly with cultivar, season and quality, from about $2 to $12/kg. Average prices are about $4–5/kg for lychee, and slightly higher for longan

Gross margins have been calculated for lychees on the Atherton Tableland in northern Queensland. With a yield of 55 kg/tree and a planting density of 140 trees/ha (7.7 t/ha), estimated gross margin (income minus variable costs) was about $21,570/ha. These figures assumed that 50% of fruit was sold as first class at $6/kg, 40% as second at $5/kg and 10% at the farm gate at $4/kg.

The gross margin is very sensitive to price. With 50 kg/tree, it is $20,060 at $5.40/kg and only $9,048 at $3.60/kg. Further details of the economics of growing lychees and longans can be obtained from the Queensland Department of Primary Industries at Mareeba.

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Mangosteen

John Downton

The late Elias Chacko

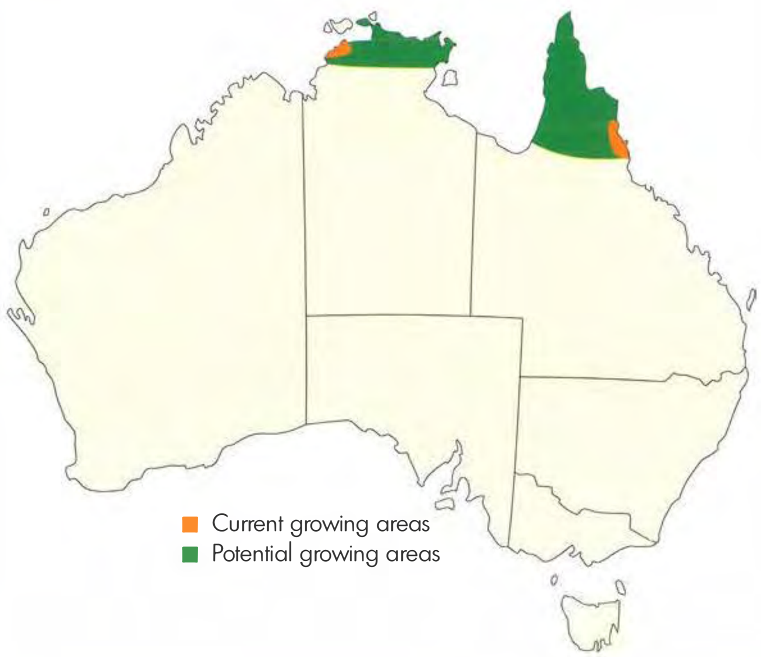
Introduction

The mangosteen (*Garcinia mangostana* L.) is a tropical fruit relatively unknown in Australia but which sporadically appears on some of the larger markets here. It is better known in South East Asia, where the crop originated, and the major producing countries are Thailand, Malaysia, Philippines and Indonesia. Most of the fruit in these markets is obtained from backyard trees or from trees planted as a component of mixed fruit orchards. Outside South East Asia mangosteen has proven difficult to cultivate on a broad scale. In Australia, around 10,000–12,000 trees (about 50 ha) have been planted in the Northern Territory and far north Queensland.

Mangosteen, native to the wet tropics, is adapted to heavy and well-distributed rainfall and has been described as the 'Queen of Tropical Fruits' because of its instant visual and taste appeal. This fruit could undoubtedly find a significant niche on the Australian domestic market, and export possibilities also exist due to the fruit's good transport characteristics and its relatively long shelf life. Australia enjoys a partial 'reverse hemisphere' production advantage over Asia and could become a world focus of mangosteen production. Pioneering research on early establishment requirements has already made considerable progress, particularly with respect to propagation, shading, nutrition and irrigation. Recommended agronomic practices for mangosteen are often based on field observations in specific locations, rather than on scientific experiments. Successful growers will be those with an intense interest in the crop and a willingness to experiment to further accelerate early plant growth and to induce precocious, reliable flowering.

Markets and marketing issues

Mangosteen fruit is normally consumed fresh and tends to lose its delicate flavour when preserved. Market intelligence on the crop is limited but indicates a potential for market growth. Since there are few suppliers, the fruit sells for relatively high prices outside of South East Asia, e.g. $A3 per fruit on the London retail market and $A2–3 per fruit in Sydney and Adelaide. Wholesale prices in Sydney are $A50–$A60 per tray (20–30 fruit). In Australia, a challenge for market development will be to significantly and reliably increase production of the crop so as to



enable it to become more generally known in the domestic market, to reduce the current high prices which are an impediment to consumers and to provide continuity of supply to potential export markets.

Currently, the major producing countries are Thailand (130,000 t from 15,000 ha in 1995), Malaysia (27,000 t from 2,200 ha in 1987), Philippines (2270 t from 1130 ha in 1987) and Indonesia (2500 t in 1975). Thailand is the major exporter of mangosteen fruit to international markets($US5m). Export from Indonesia has increased dramatically during recent years, from 452 t in 1991 to 2235 t in 1994.

Production requirements

Mangosteen is a shade-tolerant, understorey tree adapted to the humid, wet tropical lowlands of South East Asia. In Australia, it is currently grown in the wet tropics of far north Queensland (Cairns, Mossman, Innisfail) and the seasonally wet/dry tropics in Darwin. Irrigation is required during the 'dry' period to maintain soil moisture at or near field capacity to a depth of at least 0.5 m. At Darwin, shading is required for at least 10 years after planting to prevent leaf burning, which is caused by high solar radiation levels in combination with low humidity, high temperatures and wind. In far north Queensland, shading is required only during the first two years after field planting.

Trees are transplanted from the nursery to the field in which established banana or other shade trees provide natural shelter. Banana is useful as a short-term cash crop to bridge the long period before mangosteen becomes productive. It also adds large amounts of organic matter to the soil and improves the microclimate around mangosteen trees by increasing the relative humidity and lowering temperature. Leguminous trees such as *Inga edulis* (ice-cream bean) when planted for permanent shade also add nitrogen to the soil.

Mangosteen grows best in the wet tropics where rainfall is frequent, and supplementary irrigation is available during dry periods. A high water table seems to favour growth, provided the water is free-moving. It has been observed that mangosteen grows best along river banks and near ponds or lakes. Preferred soils are rich in organic matter and slightly acidic. The optimum temperature range for growth is 25–33°C with over 80% relative humidity. The tree makes little growth below 20°C and is killed at 5°C.

Varieties

Mangosteen lacks genetic variation since the seeds are formed apomictically (without fertilisation). The flowers on commercial trees are female only; male trees have been reported, but are rare. Some clonal variation may exist based on reports of a larger fruit size in countries such as Malaysia, but this could be related to environment.

Mangosteen is propagated from seeds which, like many other tropical species, do not remain viable for very long. Larger seeds produce stronger seedlings. Successful germination requires prompt importation and quarantine clearance of seed from South East Asia.

About the authors

John Downton has 25 years of horticultural experience in the area of plant physiology. He recently retired as Chief Research Scientist and Assistant Chief at the CSIRO Division of Horticulture. See Key contacts for address.

The late Elias K. Chacko was a Senior Principal Research Scientist with CSIRO Horticulture in Darwin. He was known internationally for his research and experience in tropical fruit and nut crops. See also 'Cashews'

Vegetative propagation in mangosteen has been attempted by cleft grafting mature scions to seedlings of *G. mangostana* and related species such as *G. tinctoria*, *G. cochinchinensis*, *G. xanthochymus* and *G. morella*. Although precocious bearing has been observed on *G. mangostana* rootstocks, grafting has not gained favour due to significant problems with suckering below the graft union.

Key statistics

- Limited production in NT and far north Qld (10,000–12,000 trees)
- Fruit currently sold on domestic market only
- High value fruit, commanding $A2–3 retail per fruit
- Production by Thailand, Malaysia, Indonesia and Philippines exceeds 150,000 t with 5,000–10,000 t exported

Nodal cuttings taken from seedlings up to one year old root quite readily when dipped in rooting hormone and placed in sand in a hot, humid greenhouse. However, young seedlings have few nodes, which limits propagation by this method.

Agronomy

Nursery management. Mangosteen is notorious for its slow initial rate of growth and seedlings are commonly only 15 cm tall with a few small leaves after two years. However, recent Australian research has shown that early growth can be significantly promoted by improving nursery management.

Fresh seeds are germinated in small pots containing equal parts of peat moss and coarse sand. A few months later, 2–4 leaved seedlings are carefully removed with minimal root disturbance and transplanted into 10 L black polyethylene bags (160 mm diam × 500 mm length) containing a soil mix of peat moss, composted pine bark and coarse sand (1:1:1) mixed with 10 g of a controlled release fertiliser (Osmocote Plus®). This potting mix has improved growth compared with commercially available potting media, by providing better aeration and an acidic pH of 6.2. Seedlings need fertilising every three months with a repeat application of Osmocote Plus and by fortnightly application of foliar nutrient spray (2 mL concentrate per litre of water; Wuxal Liquid Foliar Nutrient, Schering Pty Ltd, NSW). The seedlings are irrigated by overhead sprinklers for 15 minutes, four times a day.

An aspect critical to growth in the nursery is the level of light provided. Optimal light levels have been shown to shift over the three-year period that plants normally spend in the nursery before transplantation to the field. Initially, seedlings need to be very heavily shaded. Experimental work in shade houses in the Darwin area shows that mangosteen seedlings can develop 9–10 pairs of leaves (flushes) in the first year when grown under 80% shade cloth. After developing these 8–9 primary nodes they commence branching and grow more rapidly through the development of increased leaf area at successive flushes. Shading levels should be reduced to 50% at this stage and further reduced to 20% in the year before field planting. In the wet tropics where frequent cloud cover attenuates sunlight, young seedlings require less shading (e.g. 50% in year 1).

Ripe mangosteen fruit showing the edible segments

Key messages

- Instant taste and visual appeal
- Tree development is slow
- Nursery management critical to success
- High rainfall or irrigation required
- Shading required in nursery and field

The slow growth of mangosteen is associated with very low photosynthetic rates of leaves. It has been shown that photosynthesis and growth can be greatly increased (60–80%) if supplementary carbon dioxide is provided, but this is unlikely to be practical for non-commercial nurseries.

Field planting and management. In the wet/dry tropics, mangosteen seedlings can be field planted at a density of 200 trees/ha in their third year. They are best transplanted just before the wet season in a non-flushing state. A nurse crop (e.g. banana) should already be present as an overstorey. During the dry season, leaves can be sprayed with kaolin suspension (5–10%) to reflect high solar radiation and heat load. If permanent shade trees are planted (e.g. *Inga edulis*), they will require annual pruning to ensure that mangosteen shading does not exceed 50%. The field-planted trees require at least 100 L/tree of irrigation water applied by under-tree sprinklers on alternate days. As trees mature, irrigation should be increased to 200 L/tree on alternate days. Fertiliser (N:P:K 15:15:15 + micronutrients) should be applied at three-monthly intervals at 0.5–1.0 kg/year for young trees (1–3 years). Mature trees should receive an N:P:K:Mg mixture (12:12:17:2) at the rate of 2.5 kg/tree. Foliar application of micronutrients may be required to correct deficiencies of zinc and iron which are common in Australian soils. In addition, regular mulching with organic manures is beneficial.

Flowering and fruiting. Although mangosteen is noted for its long juvenile phase (10–15 years), the provision of improved conditions for early growth has reduced this period to 6–7 years in trees grown in the Cairns and Darwin area. Work now needs to be done on methods to reliably induce flowering in young trees. Manipulation of plant water stress levels is a possible strategy in the wet/dry tropics, but in the wet tropics growth regulators may be required to induce flowering.

Fruit are borne on terminal shoots either singly or, occasionally, in clusters. The period from flower opening to harvest requires about 12–16 weeks and fruit is normally available during March–May in north Queensland and during September–December in the Northern Territory. Yields of 100–1500 fruits/tree have been reported from overseas, with large, but not necessarily biennial, variation between years.

Pest and disease control

Mangosteen is relatively free from pests and disease in Australia, with any outbreak being readily controlled by use of the appropriate pesticide. The major pest observed in Australian plantations is red-banded thrips (*Selenothrips rubrocinctus*) which infest flowers and damage the fruit skin. Other pests reported from overseas include tussock caterpillar (*Eupterote favia*), coconut scale (*Aspidiotus destructor* Sig.), a small ant, mites, rats and bats.

Three-year-old mangosteen seedling sprayed with kaolin for sunburn protection

Known diseases include coffee thread blight (*Pellicularia koleroga*), Helminthosporium leaf spot, Pestalozzia blight and stem canker (*Zignoella garcineae*). Postharvest diseases include *Botryodiplodia theobromae* Pat., *Diplodia* sp., *Gloeosporium* spp., *Pestalotia flagisettula*, *Phomopsis* spp. and *Rhizopus* spp. These usually result in hardening of the pericarp and the decay of the aril. The physiological disorder, 'Gamboge', which causes yellow exudate to infiltrate the aril and cause a bitter taste occurs in all mangosteen growing countries, including Australia.

Harvest, handling and postharvest treatment

Fruits are hand-picked. The optimum harvest time is when 25% of the fruit skin has developed a purple colour. At this stage the skin is resistant to mechanical damage during handling but will develop an appealing purple colour within 1–2 days of harvest and retain a relatively long shelf life. Since the fruits on a tree ripen over a two-month period, frequent harvests are required. A six-stage colour chart is available from the Institute of Industrial Scientific and Technological Research, Thailand to assist growers in determining the correct time for harvest.

After harvest, fruits are cleaned in water and graded according to fruit weight: >100 g, 75–100 g and <75g. For export markets, Thailand growers wrap each fruit in tissue paper and pack them into cardboard cartons (38 × 25 × 7.5 cm). Each box has ventilation holes and contains 24–30 fruit. Storage at 13°C is suitable for maintaining a high standard of quality, and the ideal transit temperature range is 13–25°C. Experiments have shown that mangosteen can be stored for 7 weeks at 4.5°C and 85–90% relative humidity, but hardening of the pericarp under such conditions causes a reduction in fruit quality.

Economics of production

Mangosteen is not grown as a plantation crop in the traditional growing areas of South East Asia; rather it is a component of mixed plantings in homestead gardens. As a consequence, the economics of mangosteen production have not been fully assessed. However, growers in Thailand, the major mangosteen producer in the world, have recently been profitably exporting fruits to Singapore, Japan, Hong Kong and Europe.

In Australia mangosteen is a new crop and the production levels that can be achieved in large-scale plantations have not yet been fully evaluated. Land, nursery and infrastructural costs will be similar to other horticultural tree crops. However, extra costs include seed importation and maintenance of seedlings in the nursery for three years (approx. $30/tree over three years). Finally, in considering mangosteen, potential growers should build in a long lead time to full production and ensure the use of high-value nurse crops (e.g. banana) to provide returns in the early years after establishment.

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Terminal bearing in mangosteen

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Persimmon

Ray Collins

Introduction

The non-astringent persimmon (*Diospyros kaki*) has emerged on the Australian horticultural scene in only the last 20 years, but it has a 2000 year recorded history in the Orient, and has always been among the most popular fruits in countries such as Japan and China. In fact, the persimmon is well known in virtually every Asian country.

As Asian food markets have developed over the last decade, opportunities have arisen for southern hemisphere producers to supply high quality perishable products outside the normal northern hemisphere season. This is both an opportunity and a challenge for Australian producers of non-astringent persimmons.

Australia is well placed to grow the crop because of its high quality natural resources, efficient production systems and relative closeness to Asian markets.

Both total production and total exports of persimmons have steadily increased during the 1990s, as Table 1 illustrates.

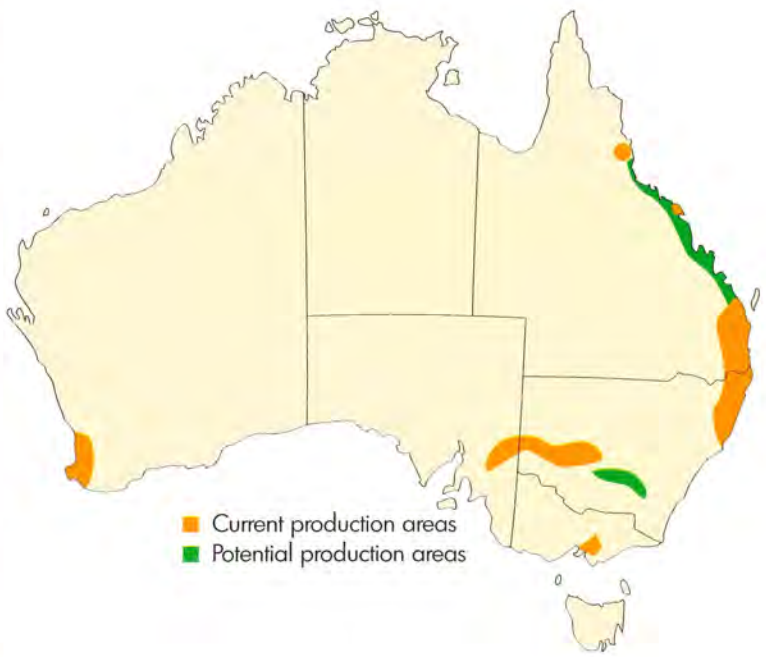
The Australian industry is currently spread thinly over all five mainland States. There is no single centre of production, though there is a marketing group, the Australian Persimmon Export Company, which has taken a central marketing role. The major competitor on export markets is New Zealand.

Growing persimmon trees is relatively easy because they are so adaptable to different soils and climate, but growing persimmon fruit for export has been rated by professional growers as very difficult.

Marketing issues

There are both domestic and export markets for non-astringent persimmons. The domestic market is small and sensitive to oversupply. Here, prices can fall to a few dollars for a single layer tray (4 kg), although prices over the 1994 to 1997 seasons have averaged around $7–10/tray at the farm gate. Export prices can be as high as $20/tray, but they average no more than a few dollars above the domestic price for fruit of comparable quality. The economics of growing persimmons is most strongly determined by what percentage of production meets export standards.

The major export market is Singapore, which takes around 70% of total Australian exports. Most other Asian countries, the Middle East and Pacific islands



represent small markets with varying potential for development. Quarantine barriers prevent Australian access to markets such as Japan, China, Korea and Taiwan. All exports are currently air-freighted because sea freight has resulted in unreliable outturns. Modified atmosphere technology for extending storage life is expected to be available soon.

The Australian marketing season extends from late February to early June. From late April onwards, competition from New Zealand, which has an industry five times bigger than Australia's, can be expected.

The centrepiece of Australian persimmon exporting is the Australian Persimmon Export Company (APEC), owned and controlled by about 40 growers from five States. APEC handles well over half of Australia's total persimmon exports, and about two-thirds of the Australia's exports to Singapore. APEC has developed its own quality management program, and two dedicated brands—Sweet Gold and Golden Star.

Production requirements

The persimmon can grow in a wide range of climates and soils, as the accompanying map indicates. The ideal climate should provide: at least 100 hours of chilling below 7°C; more than 1400 hours of sunshine during the growing season; an autumn mean daily temperature of 22.5°C, but at least above 16°C; a fruit development period of 27 weeks free of frost; and a low risk of temperatures above 35°C in the two months before harvest. The tree grows best in sandy loams of at least 1 m depth, and requires irrigation. Irrigation water should have a conductivity less than 1300 mS/cm.

Varieties

The world benchmark variety is 'Fuyu', typically comprising 70–90% of non-astringent persimmon plantings in all countries. 'Fuyu' is harvested mid-season. The most popular early varieties are 'Izu' (one month before 'Fuyu') and 'Jiro' (two weeks before 'Fuyu'), and 'Suruga' (two weeks after 'Fuyu') is the most popular late season variety. Each of these other varieties has characteristics which various markets discriminate against. 'Izu' has poor storage life, 'Jiro' has a flattened shape and 'Suruga' has skin folds around the calyx. Polliniser varieties, mainly 'Dai Dai Maru' or 'Gailey', are recommended, for planting at a ratio of 1:8 to 1:10.

About the author

Ray Collins, Senior Lecturer in Agribusiness (see *Key contacts* for address), has worked with the Australian persimmon industry for over 15 years, initiating and guiding the development of the Australian Persimmon Export Company since 1989.

A number of patented varieties bred in Japan are to be released commercially in the next year. None has been evaluated in Australia as yet. Most nurseries grow to order, so if any particular type of non-astringent persimmon is required it needs to be ordered one or two years in advance.

Table 1. Australian persimmon production and exports 1987–88 to 1994–95

Year	Total production (t)	Total exports (t)	% of production exported
1987–88	233.0	22.3	9.6
1988–89	244.5	21.0	8.6
1989–90	231.9	31.3	13.5
1990–91	328.6	33.7	10.3
1991–92	479.6	134.0	27.9
1992–93	509.7	197.4	38.7
1993–94	496.0	218.3	44.0
1994–95	640.0	472.4	73.8

Sources: Australian Bureau of Statistics, Canberra; Plant Quarantine and Inspection Branch, Australian Quarantine and Inspection Service, DPIE, Canberra.

Agronomy

Modern orchards are typically planted at 500–1,200 plants/ha. Free-standing systems are being replaced by trellised systems, particularly the palmette. Trellised orchards come into production earlier (about three years from planting to first harvest), produce a higher percentage of export quality fruit, and are easier to manage. Young grafted trees require protection from winds and predators such as rabbits during the first two years. Irrigation is usually provided through under-tree sprinklers or microjets with outputs from 40 to 150 L/hour/tree. Use of tensiometers to monitor soil moisture is recommended. Weed control during establishment is essential.

Specialist orchard equipment includes a slasher, weedicide sprayer, airblast sprayer, pruning equipment, picking bags/bins, and packing and grading equipment.

Orchard management starts with winter pruning (August), then fruit thinning to 10–12 fruitlets/m^2 of canopy surface area soon after fruit set (November). Irrigation is necessary throughout fruit development and fertiliser is applied carefully, as too much can cause fruit drop. Harvesting occurs about 27 weeks after flowering.

Pests and diseases

Persimmons are relatively free from pests and diseases, but some can be serious. Fruit fly is the main insect pest and it must be controlled. Other insect pests include thrips, fruit piercing moths, and stem girdlers, each significant in particular locations. The main disease is *Cercospora*, or angular leaf spot, which can reduce productivity through premature defoliation. A major problem for growers is that few chemicals are registered for use on persimmons.

Vertebrate pests include birds and fruit-eating bats. In many locations these are a major limitation to production, and the only successful control is to erect permanent netting over whole orchards. Netting also protects against hail.

The Sweet Gold brand devoted exclusively to export

Key statistics

1994–95 (the most recent year of data)

Total tree number	approx. 150,000
Australian total production	640.0 t
Total exports	472.4 t
Major export destination	Singapore

Harvesting, grading and packing

Individual fruit are clipped from the tree, gently placed into bins and carefully transported to the packhouse. There, they are polished by soft roller brushes or manually with a cloth. Grading takes size, shape, firmness, degree of blemish and colour into account. Fruit are packed by hand into single layer trays, each containing about 3.5 kg of fruit. Small fruit are packed 25 or 28 to a tray, medium 20 or 23, and large 12 to 18. Trays are stacked onto pallets for transport to markets. Coldrooms are sometimes used for short-term storage, but storage at temperatures below 12°C (especially 5 to 10°C) for more than two weeks causes chilling injury to fruit, making them unsaleable.

A typical export market specification for 'Fuyu' persimmon is: size 200–250 g;

colour minimum stage 4 on standard Japanese colour chart; minimum 14° Brix; no evidence of softening; virtually free of blemish; true to shape for the variety.

Key messages

- Adaptable tree
- Costly to establish
- Hard to grow quality fruit
- Demands high level management
- Not for the hobbyist

Economics

Establishment costs for a 1 ha block of 1000 trees (4 m × 2.5 m) on palmette trellis are: land preparation $1000; tree purchase @ $10 = $10,000; irrigation system (connection to an existing supply) @ $5/tree = $5000; trellis $10,000; hail netting (can delay to year 3) $25,000; planting @ $3/tree = $3000. Total cost $54,000/ha.

Summary gross margin for the above block of trees at full production:

Gross income: 4000 trays marketed per hectare at average $8/tray = $32,000/ha.

Variable costs: growing costs $9000; harvesting and packing costs $8000; selling costs $5000. Total variable costs (excludes owner's labour) = $22,000/ha.

Gross margin = $32,000 – $22,000 = $10,000/ha.

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APEC growers inspecting retail performance of their fruit in Singapore.

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Rambutan

T.K. Lim
Y. Diczbalis

Introduction

Rambutan (*Nephelium lappaceum* L.) is a very attractive, nutritious and delectable bright red or yellow fruit, popular among the Asian and European ethnic groups. It was introduced into Australia from its native Malaysia/Indonesia as seeds in around the 1890s, but clonal materials were introduced and developed after the 1960s. Although more than 50 clones were introduced, only 12–15 are commercially cultivated. The crop was introduced into the Northern Territory as recently as the 1980s.

The Australian rambutan industry remains at a fledgling stage, having developed over the past 15 years. The crop thrives well in coastal areas in north Queensland, north of Ingham (18° 50'S.) and around Darwin (12° 2'S.) to Adelaide River (12° 7'S). In Kununurra, Western Australia, rambutan does not thrive well and fruit setting is problematic because of meteorological constraints.

Thailand, Malaysia and Indonesia are the leading producers. Rambutan is grown also in the Philippines, Brunei, Vietnam, Singapore, Kampuchea, Burma, Sri Lanka, Central America, northern Australia, Hawaii, Mauritius and Madagascar. The 1990 statistics of rambutan in Indonesia list 4,593,574 trees planted in an area of 66,574 ha with a production of 270,686 t. In 1991, exports totalling 108.644 t worth US$ 201,417 were exported from Indonesia to: Singapore, 18.7 t; the United Arab Emirates, 41.653 t; Ghana, 8.06 t; Holland 3.896 t; and Luxembourg 4.146 t. Statistics for 1996 report a production of 340,000 t. Thailand produced 430 000 t from 60,000 ha in 1983–84 and exported 273 t fresh fruit worth US$179,000 to Hong Kong, France, Holland, Switzerland and other countries, and US$2,430,000 of canned rambutan with and without pineapple stuffing. Malaysia in 1994 had 17,610 ha planted with rambutan. Production periods for the various growing countries are shown in Table 1.

Marketing issues

Rambutan ranked high in an ASEAN fruit taste test in Hong Kong in 1986 showing that the Chinese like the fruit and suggesting that it has a high unexploited market potential in China and Taiwan (Fig. 1).

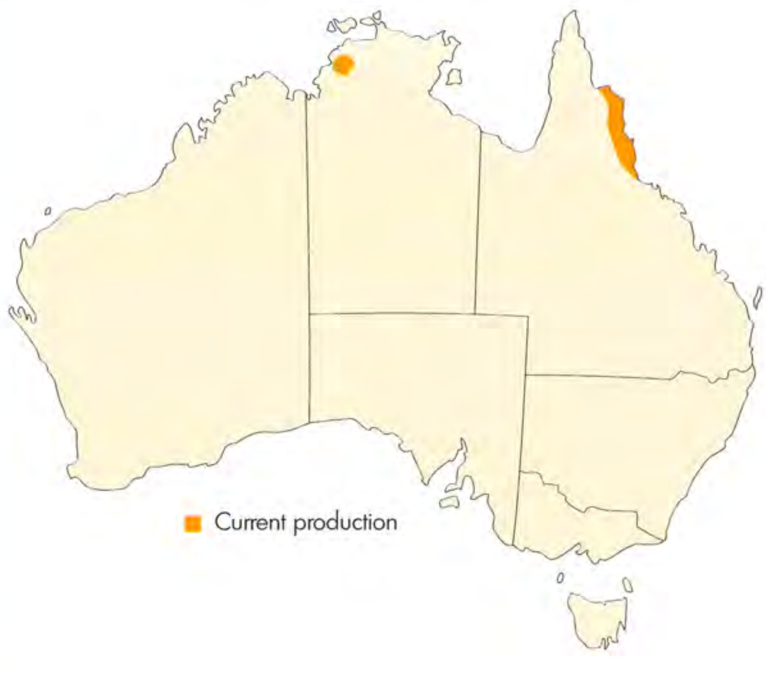

Table 1. Rambutan production periods in various countries.[a]

Production area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Thailand		Minor	Minor	Minor	Major	Major	Major	Major	Major (1st half)			
W. Malaysia			Minor (2nd half)	Minor	Minor	Minor	Major	Major	Major	Major		
E. Malaysia							Major	Major	Major (1st half)			
Indonesia	Major	Major (1st half)									Major	Major
Sumatra						Major	Major	Major	Major (1st half)			
Brunei							Major	Major	Major (1st half)			
Philippines							Major	Major	Major	Major (1st half)		
Vietnam					Major	Major	Major	Major	Major (1st half)			
Singapore						Major	Major	Major (1st half)			Minor (2nd half)	Minor
Northern Territory	Major									Major (2nd half)	Major	Major
N. Queensland	Major (2nd half)	Major	Major	Major	Major	Major	Major	Major (1st half)				
Burma						Major	Major	Major	Major (1st half)			

[a] Heavier shading indicates major crop, and lighter shading minor crop

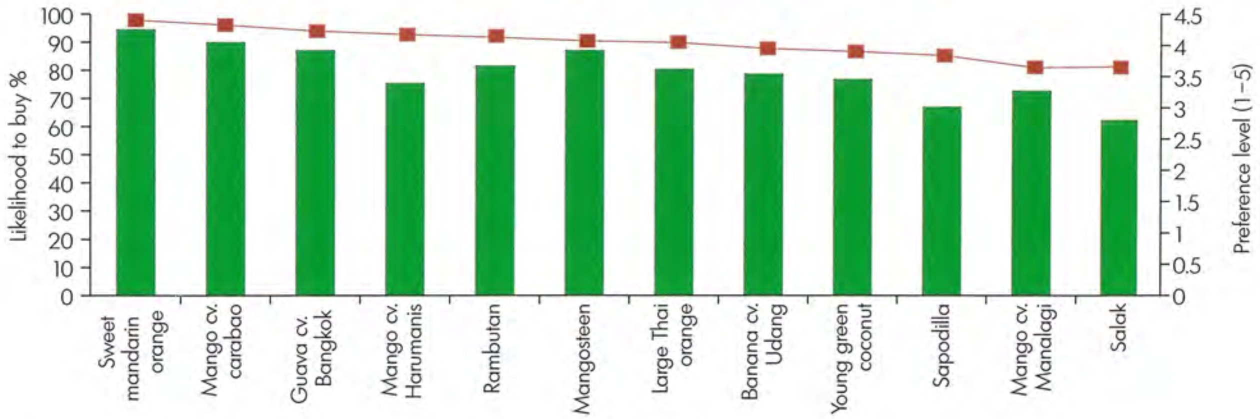

Figure 1. Results of a taste test at the ASEAN fruit exhibition in Hong Kong 1986

In north Queensland, the industry is currently worth $2m from a production of 200 t by about 60 growers. There are about 14 major growers each with about 1000 trees, but most growers have around 200–500 trees. The trees in Queensland are 10–12 years old, and yield, on average, around 100 kg/tree. In the Northern Territory, production from about 40 growers is 60–75 t and the industry is valued at $0.6–1.0m. Most growers have fewer than 500 trees. Many growers have reduced their planting size, and some have abandoned rambutan cultivation because of the catastrophic fruit losses from depredation by rainbow lorikeets. Trees are much younger in the NT and yields are lower at 45–55 kg/tree. In both areas, growers are becoming more informed and more organised with the development of the Rambutan Growers Association in north Queensland and a rambutan growers group in the Northern Territory.

The major domestic markets are in Sydney, Melbourne, Brisbane, Perth and, to a smaller extent, Adelaide and Darwin. Rambutan is sold as single layer trays (2.5–3 kg), bulked packs (5 kg) bunched panicles or in punnets (250–850 g). Bunched panicles are in demand only around Chinese New Year, which falls in either January or February. Punnet packaging is slowly gaining acceptance in domestic markets. In general, prices received by growers in the Northern Territory are higher, averaging more than $20/2.5 kg tray because of the early market window and absence of competition from Queensland, where average prices obtained are much lower. From June to October, production levels are minimal but prices would be higher because of less competition from deciduous fruits. Currently, domestic prices are higher than export prices.

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Ripe rambutans

Rambutan presently commands a small market size in Europe but expectations for future growth are high. Major markets are France, the Netherlands, the United Kingdom and Germany. Small quantities of rambutan have been exported from Australia since 1987. In 1992–93 a total of almost 10 t was exported to Bahrain, Brunei, France, Hong Kong, Kuwait, Lebanon, New Caledonia, Papua New Guinea, Saudi Arabia, Singapore, United Arab Emirates and United Kingdom.

Industry's strength and weaknesses

Some of the industry's strengths are:

- almost year-round Australian production (except September and early October)
- diversity of high yielding commercial cultivars
- good preharvest management technology and postharvest handling system
- red cultivars not a preferred host for papaya fruit fly
- good domestic demand for fresh fruit
- good opportunities and market exist for canned rambutan products
- attractive packaging and quality assurance standards exist
- clean green image.

The industry's weaknesses include:

- short shelf life of fruit
- fruit susceptibility to injury and desiccation
- the crop must be protected from winged vertebrate pests by netting, increasing production cost
- poor handling of produce in retail market outlets
- lack of cohesion and coordination in group marketing, especially fragmented marketing among NT growers.

Production requirements

The native environment of the rambutan is characterised by high, evenly-distributed rainfall (around 2000 mm or more), high humidity, low evaporation rates and average minimum temperatures above 20°C. Lower temperatures will constrain growth at altitudes above 300 m. In northern Australia, the low night temperatures (< 15°C) and the low prevailing diurnal humidity during May to August can inhibit shoot development and cause young leaf, flower and fruit abortion. Controlled environment studies showed that vegetative growth ceases under cool day/night temperatures (22°C/14°C) and is only marginally better at 32°C/14°C. Maximum growth occurs at 32°C/28°C. Windbreaks are necessary because of the strong and dry winds particularly in drier growing areas.

The crop grows best in a well-drained, deep loamy soil with a pH in the range 5.5–6.5 and does not do well on alkaline soils with high bicarbonate or calcium levels. In northern Queensland, rambutan thrives best on the red basaltic soils to the west of Innisfail. Other suitable soils include the metamorphic and alluvial soils in the valleys and foothills. In the Northern Territory rambutan is grown mainly on the sandy loamy yellow-brown earths. These soils require regular fertilisation and irrigation for good plant growth.

Varieties

More than 50 cultivars have been introduced from South East Asia, several of them erroneously labelled or misidentified. About 15 are popularly cultivated in commercial orchards in the Northern Territory and Queensland (Table 2). Most of these varieties have been vegetatively propagated by inarching, marcotting or bud grafting.

Some attributes of a good variety are: a) fruit weight > 40 g with flesh recovery ratio > 45%; b) red/orange pericarp resistant to insect attacks (yellow pericarp more susceptible); c) fruit with < 5.5 spintern/cm^2 fruit surface and spintern length < 12 mm long to reduce moisture loss; d) fruit with free-stone and testa-free flesh which is firm and crisp; e) yields of 12–15 t/ha based on 8-year-old trees at a spacing of 100 tree/ha; and f) tolerant of temperatures below 15°C.

Table 2. Some characteristics of popular commercial rambutan clones.

Clone	Colour	Origin	Shape	Mean flesh:fruit Ratio %	Mean spintern length (mm)	Mean spintern density no/ cm^2
Binjai	red/orange	Indonesia	round/ovate	40.13	14.0	6.5
Jitlee	orange/red	Singapore	round	36.20	15.0	6.2
Lebak Bulus	red	Indonesia	round	53.18	11.5	7.3
R3 (Gula Batu)	red	Malaysia	ovate	53.66	16.5	7.2
R7	orange/red	Malaysia	ovate	45.54	11.4	7.8
R9	red/orange	Malaysia	oval	37.12	13.1	7.5
R99	scarlet red	Malaysia	ovate	41.39	12.9	5.1
R134	orange/red	Malaysia	ovate	42.65	14.4	6.6
R156	yellow	Malaysia	round	60.03	9.60	6.8
R163	yellow	Malaysia	ovate	59.61	10.8	6.6
R167	orange/red	Malaysia	ovate	43.83	14.6	7
R168	red	Malaysia	oblong	48.80	14.5	5.1
Rapiah	red/orange	Indonesia	round	42.29	12.2	7.1
Rongrein	red	Thailand	round	41.00	16.6	7.00

Key statistics

Australian production

Queensland	200 t/year, estimated value $2m
Northern Territory	60–75 t/year, estimated value $0.6–1.0m

Cultural practices

The most common planting distance for rambutan is 8–10 m within rows and 10 m between rows in a square or triangular planting system giving densities of 100–150 trees/ha. A few orchards have wider tree spacing of 12 m × 10 m giving a density of 80 trees/ha. In the Northern Territory, to avoid attack by rainbow lorikeets, it is recommended that rambutan be established under some form of permanent overhead netting, in which case densities of 200–300 trees/ha, i.e. planting distances of 4–6 m by 8 m are desirable. Under such a regime, annual topping and hedging of trees is necessary, in addition to the usual pruning inside the canopy and skirting.

A windbreak established 8–10 m from the crop row along the windward side is a necessity for most areas in Queensland and all areas in the Northern Territory because of the strong, dry and cold south-easterly winds from May to August and the threat of strong cyclonic wind during November–March. Windbreaks should be established before the rambutan crop.

Maturing rambutan fruit in north Queensland

Fruiting terminals and other strong leaders are usually pruned back 0.3–0.5 m after harvesting. Weak growths and shoots inside the canopy are also cut away and branches drooping to the ground are skirted. In the Northern Territory, where it has become necessary to establish rambutan overhead netting, topping and side hedging has to be done annually or biennially.

Mulching is good for young trees. Sugar mill waste such as bagasse or molasses, paper waste, hay, polythene, well-decomposed poultry and animal manure are often used. Mulching increases soil moisture and organic matter, raises humidity and carbon dioxide in the tree micro-environment, reduces weed growth and soil erosion, alters soil pH and insulates tree surface roots.

Root distribution investigations on mature trees showed that 80% of the root system is in the top 15 cm of the soil and within the canopy line, indicating that rambutan is shallow-rooted. Anecdotal evidence indicates that severe leaf drop occurs following 10 days without irrigation. Experiments using potted, mature, field-grown trees showed a rapid decline in leaf water potential and CO_2 assimilation 3 days after cessation of irrigation. These data suggest that irrigation should be frequent (daily) after the wet season, and that during periods of high water requirements (fruit filling) twice-daily irrigation may be appropriate, particularly on sandy soils.

Crop factors have been developed from crop monitoring in the Northern Territory (Table 3). They can be used to calculate approximate water requirements for trees. Growers should note that the evaporation-based system of water requirement estimation is a valid means of assessing water use for the design of irrigation systems for new orchards and for a starting irrigation level in existing orchards. Day-to-day irrigation management should be carried out using one of the many soil moisture monitoring instruments available, such as tensiometers, neutron moisture probes or capacitance probes.

Studies in the Northern Territory have revealed that rambutan requires more nitrogen and potassium than phosphorus, especially during fruit set and development. It also requires the following macro-elements in decreasing amounts: N > K > Ca > Mg > P. For the first two non-bearing years, a N:P:K (10:4.5:8) fertiliser applied 6 times/year is recommended at a rate of 1 kg [per tree?] in the first year and 1.5 kg in the second. For fruiting trees, 4–6 split applications of a chloride-free N:P:K fertiliser 10:5:9 applied at a rate of 2 kg/ tree for a three-year-old tree are recommended, increasing 0.5 kg for each year of age. Critical times for application are: at the tail end of harvest; during March; a month before flowering; and during fruit set and development.

Rambutan commonly suffer from deficiencies of zinc, iron, boron and sometimes manganese. Deficiencies can be corrected by foliar sprays or soil applications *via* soil drenching or fertigation. Foliar applications are timed to coincide with the appearance of new vegetative flushes. Rambutan leaves are sensitive to chlorine levels above 0.018%.

Calcium and magnesium fertilisers should be applied in adequate amounts during January in alternate years (e.g. dolomite 250-500 g/tree). Gypsum can also be used to increase soil levels of calcium and sulfur, especially on alkaline soils.

The levels of macro-elements in soil do not fluctuate as widely as in the rambutan leaves because of the good buffering capacity of the soil. Soil pH and electrical conductivity are also fairly uniform, pH varies slightly from 6.1–6.35 and electrical conductivity hovers around 0.05 mS/cm.

Key messages

Last longer and look better in punnets

Table 3. Suggested crop factors developed from irrigation monitoring work in the Northern Territory.

Period	Crop factor	mm per day	litres/tree/ day	litres/tree/ week
End wet to flowering	0.6–0.8[a]	4.2–5.6	100–134	700–940
Flowering to early fruit fill	1.0	7.0	168	1176
Early fruit fill to harvest	1.2	8.4	200	1400
Harvest to end of wet	1.0	7.0	168	1176

Based on: tree Size (radius 2.5 m) - Canopy cover 25 m^2, Evaporation = 7.0 mm/day
Diczbalis (1997).
[a] Lower crop factor to be used when promoting earlier flowering.

Pest and diseases

Winged vertebrate pests pose a severe biotic constraint to the cultivation of rambutan in northern Australia. Rainbow lorikeets, *Trichoglossus haematodus*, can cause catastrophic losses in yield in the Northern Territory, ravaging young, maturing and ripe fruits; while flying foxes, *Pteropus alecto* (black flying fox) and *P. scapulatus* (brown flying fox) damage ripe fruits (Lim *et al.*, 1993). In Queensland, the flying foxes are more damaging as the harvest season is longer.

Numerous caterpillars, especially loopers such as the castor oil looper, *Achaea janata*; and the conspicuous looper, *Oxyodes tricolor*; and other flower grubs damage young foliage and inflorescences. Beetles such as swarming leaf beetles, *Rhyparida* spp.; red shouldered leaf beetles, *Monolepta* spp.; leaf eating weevil, *Myocerus* sp.; and plant hoppers (Flatidae: *Colgaroides* sp., *Syrhanta* sp.) feed on the foliage and the latter on inflorescences. Red-banded thrips, *Selenothrips rubrucinctocs*, can be problematic on young foliage and fruits, causing the latter to be russeted. Fruit spotting bugs, *Amblypelta* spp., cause dark blemishes on fruit. Flatids, mealy bugs and scales also infest inflorescences and fruits. They disfigure and enhance deterioration of fruits. They are cultured and spread by ants which feed on the honeydew they secreted. Also, the honeydew secreted promotes the proliferation of sooty mould fungi on the foliage and fruits. One way to control the mealy bugs and scales is by controlling ants and keeping the trees well skirted so that the branches do not touch the ground. In certain seasons, red spotted mites also attack the fruits.

Diseases are less problematic than winged vertebrate or insect pests. Stem canker (*Dolabra nepheliae*) is common on the trunk, branches and twigs, especially when the canopy is thick and full. Pruning to facilitate more light penetration can reduce the incidence as will spraying with a copper fungicide containing no chlorine. *Lasiodiplodia theobromae* has been reported as causing dieback of branches and trunk lesions, while another fungus *Thyronectria psuedotrichia* has also been implicated in dieback. Algal leaf spots characterised by felty, orange-brown spots are caused by *Cephaleuros virescens* and can be controlled by copper sprays. Fruit rots of rambutan are caused by *Colletotrichum gloeosporioides* and *Phomopsis* sp. Stem end rots of fruits are caused by *Phomopsis* sp. and *Dothiorella* spp.

Harvesting and postharvest handling

Rambutan is non-climacteric and must be harvested when ripe. The fruit is usually harvested 2–3 weeks after colour change or when the total soluble solids (brix) level of 18–20° is reached. Harvest should be done early morning. Depending on market or labour requirements, whole panicles or individual fruits are selectively picked and placed into crates in the shade. Rambutan loses its attractive appearance after a few days under ambient conditions due to superficial browning of the fruit skin. It turns brown and eventually black because of water loss from its spinterns and skin, and from mechanical damage to the fruit. Immediately after harvesting, fruits should be rapidly transported to the packing shed. The fruits are hydro-cooled by spraying with cool water to dissipate field heat, or water-sprayed and place in a high humidity room held at 8–10°C. Many orchards in Queensland have developed a postharvest handling system which includes destalkers, dip tanks, sorting tables, a size grader and an area for assembling cartons and packing. There are no major quarantine restrictions on interstate marketing of rambutans, except to Western Australia which requires fruits to be treated with dimethoate.

Depending on the market requirement, fruits are packed in single, double or multi-layers in cartons with various polythene liner wraps e.g. peak-fresh bags, LD polybag, PY 7 bag, PVC film, or in plastic punnets and kept refrigerated at 8–10°C. Wraps are essential to decrease desiccation of fruits and to increase the shelf life to several weeks by atmosphere modification. The minimum size of carton is 2.5 kg. The fruits are transported to interstate markets by refrigerated trucks or by air.

Economics of production

The most recent economic analysis shows that profitability of rambutan is high with a yield of about 10 t/ha and if a southern wholesale market price of $5/kg can be maintained in the long term. Any improvement in yields or prices, or reduction in production cost, will increase profitability levels. The financial analysis shows that, at a long-term average price of $10–5/kg. the internal rate of return (IRR) ranges from 9.59% (low yield, 60 kg/tree) to 13.9% (high yield, 70 kg/tree) for the fixed netting system. Returns from row netting are higher, from 10.3% (low yield) to 14.37% (high yield). These rates are equivalent to 13.09–17.4% (for the fixed net planting) and 16.8–17.87% (for the row net planting) in nominal terms, assuming a long term inflation rate of 3.5% per year. In the Northern Territory, depending on the yield and netting system, the break-even price is found to be $4.50–5/kg and the payback period at this price ranges from 7–9 years. In north Queensland, where the yields are higher and the need to net trees is not so great, the break-even price and payback period are lower. Also the IRR is higher, despite slightly lower average prices.

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Grain Legumes

Adzuki bean

Peter Desborough
Robert Redden

Introduction

Adzuki bean (*Vigna angularis* (Willd.) Ohwi and Ohashi) is an important, traditional pulse crop in eastern Asia. The grain resembles mung beans, but has a maroon seedcoat and is usually slightly larger. Major consumers include Japan, China and South Korea. The seed is used in many different ways in these Asian countries, but the most common is highly sweetened bean paste with a range of different flavours and textures, as well as sweet soups and desserts. Bean paste is made into a large range of cakes, buns, confectionery, ice blocks and drinks.

Good opportunities exist for export of grain from Australia, particularly to Japan, where many of these products are considered luxuries, which is reflected in the high prices paid for best quality grain. Japan imposes import quotas on grain each year, based primarily on its domestic production, and this leads to some market volatility. Value adding through paste manufacture in Australia would lead to more stable returns to growers.

Adzuki bean is grown in summer in Australia. It is considered more difficult to produce high yielding crops of good quality adzuki bean than of mung bean or soybean. Growers need skills in irrigation, weed and insect management to get the best results.

Markets and marketing issues

Most grain is traded through grain dealers who may issue contracts and supply seed. Harvested grain has to be stringently graded to produce a uniform and attractive sample, especially if it is intended for export. The major part of the Japanese market is for 'Erimo' type, represented in Australia by the varieties Bloodwood and Erimo. A small, niche market exists for the larger 'Dainagon' type, with seed of this variety now available in Australia.

Production in Australia in recent years has been influenced by price projections, with approximately 1500 t produced in 1994, 500 t in 1995, and 1500 t in 1996. Estimated production for 1997 is 2000 t.

Areas of significant production of adzuki beans during 1994–97, with the size of the shaded area reflecting the area of production.

Japanese buyers of 'Erimo' type adzuki beans look for large seed (12–14 g/100 seed) with red rather than deep maroon colour and uniform size and shape. In recent seasons, prices received by Australian producers for high quality, graded grain have ranged from $A750 to $A1500/t. 'Dainagon' grain must be larger (>16 g/100 seed) and is usually a darker colour than 'Erimo' type. Little 'Dainagon' has been traded to date, so price trends are unknown, although expectations are for prices higher than 'Erimo' type where a market exists.

Key statistics

In 1997, 2000 t produced in NSW and Queensland, with most exported to Japan. Small quantity sold locally for small-scale domestic processing.

Japanese imports for quota grain come mostly from China for grain of lower quality, and from the USA, Australia and Argentina. Seasonality is an advantage to Australia over northern hemisphere product, as freshness is a positive quality factor. There are currently no import quotas on adzuki paste into Japan, which makes value adding in Australia more attractive.

Production requirements

Adzuki beans are a summer crop and are considered more demanding than some other pulse crops, such as mung bean or soybean. Trials in Victoria, Tasmania and South Australia have produced only poor crops. Successful crops have been produced in many areas in NSW and Queensland (Fig. 1), using techniques that have evolved over time and are specific to the special requirements of each environment. Good yields of 2.5–3.0 t/ha have been achieved, with most growers able to harvest 1.5–2.0 t/ha. In irrigation areas the recipe for success involves selection of well-drained soils and frequent irrigation to alleviate moisture stress. Adzuki bean prefers milder summer temperatures and higher humidity, and under those conditions, such as are found in northern coastal areas of NSW, it will produce high yields and tolerate waterlogging better than in inland irrigation areas. Quality appears to be higher where pods can develop under milder temperatures, achieved by sowing later in summer (January) or growing in more elevated areas, such as the NSW Northern Tablelands. Excessive summer heat can result in poor quality (small and dark-coloured seed) and in yield loss from a condition called 'Gummy pod'.

Varieties

Adzuki cultivation in Australia in recent times started in the early 1970s, with the introduction and testing of a northern Japanese variety by Dalgety Australia. This later became known as 'Dalgety' line and met with limited success. Starting in the mid 1970s in coastal northern NSW, a research and development program by NSW Agriculture lead to the release in 1980 of the variety Bloodwood which eventually replaced 'Dalgety'. Bloodwood was derived from the old Japanese variety Hikari, grown on Hokkaido where nearly all adzuki beans are grown in Japan. These two varieties, and varieties released more recently in Australia, exhibit similar adaptation to Bloodwood, in that they are mildly sensitive to short days, with rate of development determined mostly by accumulated temperature (heat sums).

About the author

Peter Desborough is a Senior Research Agronomist with NSW Agriculture at Grafton and has over 20 years experience with adzuki bean research and development in Australia, including release of the variety Bloodwood in 1980.

Robert Redden is a Principal Plant Breeder for legumes in Queensland DPI, with national leadership of Phaseolus bean programs in Australia, and ACIAR projects on adzuki beans with China and Phaseolus with the Centre for Tropical Agriculture, Colombia.

See Key contacts for the authors' addresses.

Flowers and developing adzuki bean pods

Erimo is the most widely grown variety in Hokkaido and was released in Australia in 1997. It is similar in yield to Bloodwood in areas suited to growing adzuki beans and tends to be slightly shorter. Seed size is on average a little larger in Erimo.

Dainagon was released in 1997 to cater for the very limited market in Japan for adzuki beans with larger seeds.

Agronomy

Publications containing detailed information on growing adzuki beans in Australia are listed in 'Key references'.

Adzuki beans are more often grown using narrow row spacings (15–30 cm), at high plant densities—500,000 to 600,000 plants/ha. However, wider row spacing with inter-row cultivation has produced good results, particularly in Queensland. The optimum sowing time in NSW and southern Queensland is from mid November to mid December. In coastal NSW, sowing in January will often result in better quality grain than from earlier sowing times, although yields may be lower. In Central Queensland, February sowings are preferred to avoid the heat of midsummer. The growing period, from sowing to harvesting, can be from 80 days in northern areas to 120 days in central NSW.

Irrigation management is critical to success with adzuki beans in inland irrigation areas. Even one short stress period can result in uneven ripening and reduced yields, and in fall in grain quality. Irrigation intervals need to be short, as little as 5 days, which places increased time demands on the grower. Low tolerance to waterlogging means adzuki beans should be grown only on better drained soils.

Pest and diseases

Adzuki beans are slow growing in the first few weeks and can be swamped by faster growing weeds if these are not controlled. Herbicides to control most broadleaf and grass weeds are readily available.

Many types of insect pest will attack adzuki beans and can cause serious losses. These range from leaf and pod-eating caterpillars such as Heliothis, Lucerne Seed Web Moth and Bean Podborer to pod-sucking species such as Green Vegetable Bug, as well as thrips, aphis, bean fly and mites. Crops must be inspected regularly and appropriate control measures taken. Growers need to budget on at least two insecticide applications and up to four applications in some seasons.

Crop of adzuki bean close to maturity

Table 1. Comparison of returns from adzuki and some other crops in the Forbes, NSW district.

	Adzuki	Soybean	Maize	Mung	Lucerne
Expected price ($/t)	1010	368	153	520	140
Expected yield (t/ha)	1.9	2.9	9.0	1.8	12.62
Total variable costs ($)	710	458	614	492	872
Gross margin ($/ha)	1226	459	771	492	783

Key messages

- High value pulse crop for Asia
- Limited, but lucrative local and export markets
- Scope for value adding in Australia
- Requires good farmer skill levels

Diseases have not been a major problem in commercial crops to date, with only isolated instances of Sclerotinia and Powdery Mildew. Severe heatwave conditions in 1997 resulted in a condition known as Gummy Pod in crops in central NSW, with a sharp yield reduction in some crops.

Good quality adzuki bean seed

Harvesting

Under the right conditions, adzuki crops will mature over a relatively short period, with rapid leaf loss and quick seed moisture decline. However, indeterminacy can be a problem in crops maturing in warmer weather, in crops where yield is poor and in sections of a crop where watering has been uneven or moisture stress has occurred at some stage during pod-fill. This is seen as secondary flowering flushes and green patches in an otherwise mature crop. Desiccation can be a useful harvesting aid, but must be applied only when leaf drop has started, as seed damage can occur if applied earlier.

The crop can be harvested with conventional headers, but care must be taken to ensure seed cracking is kept to a minimum and no soil particles are included with the grain. Rotary headers generally do a better job of harvesting a high quality sample.

Japanese buyers look for a uniform sample with large seed (12–16 g/100 seed) and bright colour (more red than maroon). Grain will need to be rigorously graded to ensure uniformity and freedom from extraneous matter such as soil, other plant matter, cracked or damaged seed and other species such as soybean or mung bean. Selecting pure planting seed and paddocks unlikely to have carryovers from previous crops helps freedom from these species.

Most adzuki grain is traded through merchants, who will usually arrange grading and marketing.

Economics of production

The profitability or attractiveness of adzuki bean production depends on the locality where they are grown and the range of alternative crops available. In an economic analysis across current production areas (J. Page, pers. comm.), adzuki beans were not as profitable as cotton, lucerne or peanuts in Queensland areas where these crops could be grown. In coastal NSW, the adzuki beans were more profitable than soybeans, the only comparable crop.

In the Forbes district, where most adzuki beans are currently produced, other crops gave lower returns (see Table 1) based on 1996 figures, although adzuki beans are used as a useful rotation with lucerne.

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Key references

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Black gram

Bruce Imrie

Introduction

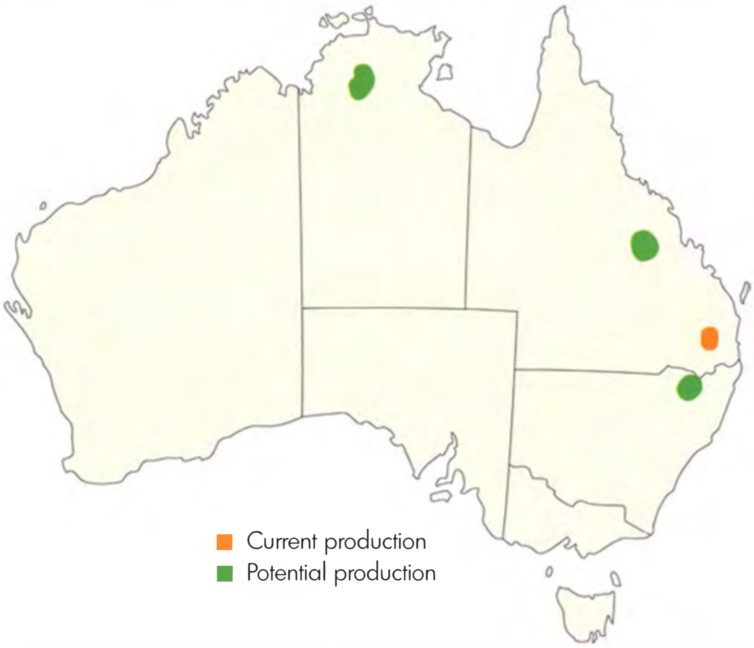
Black gram is, like mung bean, a member of the Asiatic *Vigna* crop group. It is a warm season annual pulse grown mostly as an opportunity crop in rotation with cereals. In Australia, black gram is marketed under the generic term 'mung bean'. Black gram seeds are dull grey to black. Black gram's main advantages are that, being a legume, it does not require nitrogen fertiliser application, and has a relatively short (90–120 days) growth duration. Black gram is an indeterminate plant and produces pods in groups of 2–4 in leaf axils throughout the foliage. Because of its indeterminacy, maturity can be uneven, with consequent harvest difficulties. This is most pronounced when early sowing and/or hot, moist conditions promote excessive vegetative growth and a tendency to vine.

Black gram is grown mostly in Wambo Shire in south-eastern Queensland, with production being less than 5000 t/year. Separate statistics are not kept for black gram, the crop being included with mung bean. Most of the crop is exported, with the main destinations being Japan and South Asia. The main producing countries are India and Burma, and the largest importers Japan and India.

Production requirements

Only one variety of black gram, Regur, is available in Australia. Regur is relatively day-length insensitive but, because it is an indeterminate plant, it has a more restricted planting window than mung bean. Research is currently being conducted to determine optimum sowing dates in different environments but current recommendations are that black gram be sown between mid December and mid January. Trials have indicated that Regur is much better adapted to southern Queensland than to areas further south or north. The optimum temperature range for growth is 27–30°C. A dry harvest period is desirable as this forces the crop to mature and reduces the risk of weather damage, although black gram is less susceptible to this than mung bean.

Black gram will grow on most soils, with a preference for loams with a pH of 5.5–7.5. Root growth can be restricted on heavy clays, with a consequent limitation to growth. Black gram is more tolerant of waterlogging than is mung bean.



Black gram in flower

Crop agronomy

Choice of a paddock is important because black gram pods are set throughout the plant and the header cutter bar must be set as low as possible for harvest. Consequently, a paddock with a smooth surface with no sticks, stones, or low spots is required. There should be at least 60 cm water in the soil profile at sowing.

A seeding rate to achieve a plant population of 200–300 thousand plants/ha is recommended. The crop is usually sown with row spacings of 30–60 cm depending on yield expectations, planting equipment, stubble management and rotated crops. For example, when there is a full profile at sowing and a high yield is expected, narrower rows are preferred, while in a minimum till system with stubble retention wider rows are necessary. Narrow rows and high populations are desirable for late sowings to achieve some compensation for the yield limitation due to small plant size.

Nitrogen fertiliser is usually not applied but it is advisable to use Rhizobium inoculum on the seed, particularly when the crop is to be grown in a paddock that has not been sown to either black gram or mung beans for several years. Phosphate fertiliser is usually required at 5–10 kg P/ha on dryland crops and 10–20 kg P/ha on irrigated crops. Higher rates may be required if the crop is grown after a long fallow when VAM levels decline, or on severely P deficient soils. Black gram is also sensitive to zinc deficiency which can be corrected by a soil application of zinc sulphate monohydrate pre-sowing or a foliar spray of zinc sulphate heptahydrate.

About the author

Dr Bruce Imrie is a Project Leader in CSIRO Tropical Agriculture in Brisbane (see *Key contacts* for address), where he has been a breeder of pulse crops for more than 20 years.

Weed control reduces competition during growth and improves yields but, more importantly, the presence of weed seeds in the harvested crop can cause the seed to be downgraded in quality. Several herbicides are registered for use on black gram, including both pre- and post-emergence herbicides for control of broadleaf weeds and grasses. Advice on suitable herbicides can be obtained from local traders and/or chemical companies.

Insect pest control is also important to achieve high seed quality. The following are the main insect pests of black gram.

- Green mirids and thrips, which are flower feeders and cause flower and pod abortion leading to yield reduction and uneven maturity.
- Heliothis and *Maruca* caterpillars which feed in flowers and on developing pods. They can cause a large reduction in both seed yield and quality.
- Bugs such as the green vegetable bug, red banded shield bug, pod sucking bug and brown bean bug which stick their proboscis into pods and seeds and cause

various levels of damage depending on the stage of growth of seeds at the time of attack. Black gram is less susceptible than mung bean to bug damage, possibly because of its very hairy pods.

Chemical control involving one or two sprays is usually necessary but care is needed in choice of insecticide and the time and method of application to achieve maximum effectiveness. Because the flowers and pods are located throughout the canopy, it can be difficult to get good coverage with contact sprays. Many growers employ a bug checker to monitor crops and advise on control measures.

Black gram is susceptible to diseases caused by fungi, bacteria and viruses, but their effects are usually not severe in the growing crop. Seedling loss sometimes occurs due to Sclerotinia, particularly in stressed crops sown into cereal stubble. Various leaf and stem pathogens such as powdery mildew and bacterial blight are frequently seen but do not cause much damage. Regur is more tolerant of powdery mildew than are most mung bean varieties. Plants affected by legume little-leaf disease, caused by a Mycoplasma, are frequently observed in black gram crops but rarely at a frequency to cause significant yield loss. The most serious disease of stressed plants is tan spot caused by *Curtobacterium flaccumfaciens*. The most common symptom is a leaf spot, but when infection is severe, systemic symptoms of stunting and poor pod and seed set occur.

An important disease of black gram is charcoal rot when seed is destined for sprouting, and infection precludes seed lots being classified sprouting grade. The causal organism is extremely widespread in cropping soils, and attacks a range of species.

Key messages

Black gram is a high value pulse crop in which the only available cultivar, Regur, is best adapted to the Darling Downs region of Queensland.

Black gram is a member of the Asiatic *Vigna* crop group and its management is similar to mung bean with which it is grouped for marketing.

Because of its indeterminate growth habit, the crop is not as easy to harvest as mung bean.

Harvest and marketing

Black gram is a specialised food crop used primarily in South Asia for dhal production. In some countries, Japan in particular, it is used to produce bean sprouts because the sprouts have a good white colour. Black gram flour is used for making pappadams.

Harvest occurs when more than 90% of pods are mature and dry, but timing can be difficult in black gram because of its indeterminate growth habit. The crop is most popular with growers on lighter soil in areas where a dry autumn forces plants to maturity. A desiccant may be used to kill green leaf and the remaining green pods before harvest. Later sown crops may be left in the field to be frosted before harvest. This is an option because shattering in black gram is rare. Beans are easily split or damaged during heading but this can be minimised by harvesting at the correct seed moisture content (14–16%), avoiding harvest during the middle of the day, and careful attention to header settings. Small cracks in the seed coat that are not readily visible can occur with incorrect header settings or rough handling and can cause downgrading of a seed lot destined for the sprouting market. Some growers employ a harvesting contractor who specialises in mung bean and black gram.

Following harvest, beans are trucked to a grading shed where they are cleaned, graded and bagged as soon as possible. The graded seed is sampled for quality evaluation by an accredited laboratory and, following classification, a sample is usually placed with an exporter who arranges a sale. Most seed lots are sold on sample.

Economics

Black gram can be a valuable field crop, both in terms of dollar returns and in its contribution to total farm income as a leguminous rotation crop. Estimates of gross economic margins for production on the Darling Downs are presented in Table 1.

Table 1. Gross economic margins for black gram grown on the Darling Downs in Queensland.

Item	Dryland high yield	Dryland low yield
Expected price ($/t on farm)	500	500
Expected yield (t/ha)	1.0	0.6
Expected income ($/ha)	500	300
Variable costs ($/ha)	128	119
Gross margin ($/ha)	372	181

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Key references

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Buckwheat

Chris Bluett

Introduction

Buckwheat, *Fagopyrum esculentum* M., is a broad leaf, summer-growing crop with dark-hulled, triangular, starch-filled seeds. Its family is Polygonaceae, which includes docks and bindweeds. Its name comes from the German *büch* or beech, from its beech mast (beech tree seed pods) shaped seeds, and *weisse*, or white, from its masses of white flowers.

Buckwheat is grown mainly in Japan, China, Mongolia, Korea, USA, Canada, Kazakhstan, Bhutan, Russia, Ukraine, Poland, Belarus, Slovenia and Brazil. In Australia a little buckwheat has been grown in the NSW highlands and Tasmania but the crop is now spreading into new areas of NSW and southern Victoria.

There are opportunities to produce buckwheat for export to Japan and possibly other countries, and to increase the Australian market. Buckwheat is a very healthy food and many Australian consumers and food companies are becoming interested in it.

World buckwheat production is 3 million t, mostly consumed in the country of production. Japan consumes 110,000 t/ year and grows 20,000 t, importing the balance from China, USA and Canada. Australia can supply buckwheat to Japan when its northern hemisphere supplies are no longer fresh, but Chile and Argentina may also be trying to enter that market.

Australian production is in its infancy. Some buckwheat has been grown in the NSW central tablelands. Tasmania grows some for a particular mill in Japan, and Victoria sowed its first crops in 1995. Production in Australia is still small but is expected to expand over the next three years.

Markets and marketing issues

Japan imports buckwheat as whole grain and mills it into flour for making noodles (called 'soba') and breads, and into whole or kibbled kernels (groats) for soups and other dishes. In Japan, the traditions and culture associated with food are very strong, and this is particularly true of buckwheat and soba. There are references to soba in ancient food texts and it is revered for helping sustain life during several terrible rice famines.

Buckwheat harvested area, production and trade-mean of years 1992–96 (except trade which is 1992–95)

	Area	Production (t)	Imports (t)	Exports (t)
Japan	21,380	19,140	99,393	18
China	970,000	1,420,000	109	107,562
Asia (not including China and Japan)	13,595	12,035	7,470	1,014
Eastern Europe (mainly Poland)	41,008	41,159	5,789	1,920
Russian Federation	1,641,462	768,404	280	847
USA/Canada	47,160	48,510	4,235	17,957

It is essential to understand these cultural factors if export efforts to Japan are to be successful. We must be sensitive to their definitions and ideas about buckwheat quality. How we grow, harvest, handle and ship the grain are important to them and they like to feel involved.

Buckwheat is so nutritious that an old Japanese name for it is 'Meat of the Fields'. It contains rutin, which improves cardiovascular health, very high levels of essential amino acids especially lysine, high dietary fibre and excellent levels of vitamins and minerals. It is also gluten free.

Critical buckwheat quality parameters are either physical, such as volume weight and moisture content, which are easy to measure, or are characteristics such as smell, flavour and groat colour, which are much harder to determine. Grain chemistry parameters such as protein and starch quality are not yet so important.

Grades of soba include hand-made fresh noodles, high quality dried noodles and supermarket brands. The best restaurants ('soba shops') hand make their noodles from Japanese buckwheat costing up to $A4000/t while the cheapest dried noodles are made from Chinese grain costing $A600/t. Millers generally pay about $A1100/t for grain imported from the USA and Canada.

Several Australian export companies are developing markets in Japan, either through trading companies or direct to buckwheat mills. They offer contracts to growers, and provide seed supplies, advice and support. Several other countries are also showing interest in Australian buckwheat.

In other countries, buckwheat may be used in a wide variety of foods. In Australia, uses include, for example, pancake mixes, cakes, biscuits, breakfast cereals and noodles.

Production requirements

Buckwheat is a cool climate crop. Its favoured conditions of cool temperatures with a large day/night difference are found at altitude or close to the coast, not in the wheat belt. The flowers will not set seed at temperatures much over 27°C, so too many hot days during flowering will reduce yield. Seedlings can survive a mild spring frost but frost in early autumn before ripe grain is formed can severely affect yield.

Ideal production districts in NSW include the New England Plateau and Central and Southern Highlands, and in Victoria

Growth habit of buckwheat

the high valleys in the north-east, the Central Highlands and parts of the Western District and Gippsland.

About the author

Chris Bluett BAppSci(Agric.) is a high rainfall crops agronomist with over 25 years experience in south-west Victoria. His main interest is the development of new crops including buckwheat, red winter feed wheat and Linola. See *Key contacts* for address.

Various soil types are suitable, from the ironbark country of some NSW highland areas to the deep red potato soils of Ballarat. Buckwheat responds to good summer rainfall, but is intolerant of waterlogging. It can manage with little water until flowering time, when either rain or irrigation is critical for yield.

Yields vary according to growing conditions, but experienced growers with reliable rainfall or who have irrigation available should achieve 2–2.5 t/ha in all but the harshest years. Improved varieties and agronomy should increase this in future.

Buckwheat varieties

Buckwheat is an out-crossing plant so seed crops should be isolated to retain purity. Bees may well help improve yield.

Canadian varieties. The Canadian varieties 'Mancan' and 'Manor' are grown commercially in Australia, and the variety 'Manisoba' was grown in trials during 1996–97. All three varieties grow, flower and ripen in 60 days.

Japanese varieties. There are three Japanese varieties: 'Ikeda', 'Shinano Ichigo' and 'Kitawase'. The first two are tall, 90-day maturity varieties, the third is a 60-day variety resembling the Canadian buckwheats.

Japan has many landraces, and fewer cultivars produced by plant breeding.

Variety choice is based on growing season, frost likelihood, yield and customer requirements. Some Japanese buyers, for example, may prefer Japanese varieties.

Australian growers will soon have access to new improved Japanese and Canadian lines. A self-pollinating variety is being bred in Canada, and Japanese breeders are working to further improve the health-giving features of buckwheat grain.

Agronomy

Buckwheat is grown using standard cereal seeding and harvesting equipment with no special machinery or modifications required.

It is sown from mid spring to early summer and harvested in autumn. Optimum sowing time will usually depend on variety, locality and seasonal conditions. The Japanese varieties should not be late sown in districts with high autumn frost risk, and flowering in the hottest weather should be avoided if possible.

Buckwheat emerges very rapidly in a good, moist seed bed. Pre irrigating, or sowing after rain, gives far better results than sowing into dry, cloddy seed

A well-grown buckwheat crop near Ballarat in Victoria beds and attempting to irrigate for emergence.

Optimum seed rate is yet to be determined, but low seed rates are safe only in weed-free paddocks. Calibrate the seeder carefully to sow 35–40 kg/ha of large seeded or Canadian varieties and 25–30 kg/ha of smaller seeded Japanese types.

The crop responds to phosphorus (P) but in trials so far there has been less response to nitrogen (N) or to other nutrients and trace elements. Local nutritional problems should be corrected with the same treatments used in other crops. P fertiliser is best drilled with the seed at a rate of 15 kg/ha of actual P, or up to 20 kg/ha in soils with very low phosphorus. If symptoms resembling N deficiency occur, hand-spread urea test patches and watch for responses.

Experience counts in buckwheat growing, so monitor the crop carefully throughout its growth, keeping notes of events and crop progress. 'Buckwheat Check' monitoring forms, as well as assistance and advice, are available from the agronomists listed in Key contacts.

Pest and disease control

Few disease problems have occurred so far in Australian buckwheat crops, though some diseases have been reported overseas. Watch out for seedling problems from soil-borne fungal diseases and report any suspected foliar disease to an agronomist for investigation.

Few insect problems have been encountered, though brown cutworms, which can damage many spring-sown broad leaf crops, are an occasional problem in seedlings. Other potential pests to watch out for are Rutherglen bug and armyworm caterpillars, though the latter feed only rarely on broad leaf plants.

Weeds are a potential problem in some growing areas. On the Northern Tablelands vigorous summer grasses can cause serious problems. In some Victorian buckwheat districts fat hen and wild radish are encountered.

Herbicide control is being investigated but nothing is available yet in Australia. For the best weed control, prepare a seed bed, allow weeds to germinate and use a knockdown spray. Sow the crop evenly at 10–20 mm depth into a good moist seedbed, without deeper working which brings more weed seeds to the surface. Use correct sowing and fertiliser rates and avoid spaces and gaps in the crop. In many countries herbicides are seldom used, instead they grow buckwheat partly for its weed smothering capabilities.

Buckwheat is used in foods such as 'soba' noodles, bread and 'groats' in soups.

Key messages

- Buckwheat, a cool climate crop
- An excellent health food grain
- Good potential domestic and overseas markets
- Grow buckwheat on contract
- Sow into good, moist seedbed
- Harvest carefully for high quality

Harvesting, handling and shipping

Harvesting, and its timing, are critical in buckwheat growing. Getting them right is essential for high quality, and the buying companies are always on hand with advice and support, especially for their newer growers. The buyer will nominate a seed cleaning company for growers to deliver to, and advice can also be sought from that company.

Buckwheat is ready to harvest when 75% of seeds have turned black and the moisture is within the range nominated by the buyer. There will often be some unripe seeds, green stems and leaves, and even flowers still on the plant. Direct heading is sometimes possible but many crops will need desiccation or windrowing to prevent the leaves from blocking riddles and contaminating the sample.

Desiccation with Reglone® is a proven method in Australia, but windrowing, the preferred method in the USA, is being investigated.

Moisture content is critical for buckwheat quality. For export to Japan, 15% is a common specification; domestic grain may have a lower moisture content. Harvesting at a higher moisture content for immediate delivery and drying may be an option. The seed cleaner will determine the percentage of high quality grain in the sample and the buyer will pay full price for that amount. The residue will fetch a lower price for stockfeed.

Use a slow drum speed and wide concave as over-threshing increases contamination of the sample with stem pieces and unripe seeds. Unless the sample is very clean and of correct moisture, it must be delivered immediately to the cleaning plant, or the grain will deteriorate rapidly. It will develop moulds and musty odours readily detectable by Japanese or other buyers. This affects the price or makes the grain unmarketable.

Export grain is graded, bagged and shipped in containers. Several companies are developing business in dehulling buckwheat for sale to local millers to prepare flour, groats or kibbled groats for domestic consumption. The hulls are in demand for filling pillows and soft toys.

Table 1. Typical gross margin for buckwheat

Yield	2 t/ha
	@ 85% export grade
Price	
$400/t for 1.7 t	$680
$100/t for 0.3 t	$33
Gross return	**$713/ha**
Variable costs ($/ha)	
Desiccation[a]	53
Fertiliser[b]	35
Fuel[c]	25
Insurance	10
Repairs and maintenance	20
Seed	35
Sundries	5
Total variable costs	**$183/ha**
Gross margin	**$530/ha**

[a] 2 L/ha Reglone® ($30.80) applied by air, average cost $22/ha.
[b] 100 kg/ha double super at $350/t
[c] If using a contract harvester, add the cost per hectare for the contractor and halve the amounts for fuels and repairs and maintenance.

Economics of production

Costs of buckwheat growing are comparable with other grain crops. At present, spraying for weeds is rarely required. However, growers will incur a cost for desiccation or windrowing of buckwheat. Fertiliser rates are not high and seed rates moderate. Access to ground preparation, sowing and harvesting equipment is essential.

Key contacts

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Table 2. Sensitivity of gross margin to changes in yield, quality, price and costs

Yield t/ha	2.0	**2.5**	2.5	2.5	**1.5**	2.0
% export grain	85	85	**90**	85	85	85
Price $/t (export grain)	400	400	400	**500**	400	400
Gross return	713	888	925	1101	510	713
Variable costs	183	183	183	183	183	**250**
Gross margin	**530**	**705**	**742**	**918**	**327**	**463**

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Cool season pulses

John Hamblin

Introduction

Pulses are members of the pea and clover family (Leguminoseae), a very large group of plants, many of which are useful as food (broad beans, peas, lentils, chickpeas, navy beans, grams etc.), fodder (clovers, medics, lucerne etc), building material (wattles and many tropical and sub-tropical species), industrial products (peanuts and soya beans) and many other uses. They have high levels of protein in their seeds and are an important component of diets, both human and animal, which include little meat. They also have the ability, when inoculated with the right strain of rhizobium bacteria, to fix atmospheric nitrogen in the soil. This makes them less dependent than other species on soil nitrogen, and they can even supply some of the nitrogen needs of crops that follow them.

This chapter deals with those pulses that grow in the winter in southern Australia, are harvested for their dry seeds and are eaten as a pulse or used as animal feed. Some legumes can be both a pulse and a vegetable, depending on the method of growth, the variety and the time of harvest. Peas, for example, when dried are used in soups and stews, and green peas or snow peas can be eaten as vegetables. Many pulses are a valuable addition to our diet, providing protein, fibre, minerals and vitamins. There is evidence that they reduce the risk of heart and other diseases.

The pulses produced in Australia include various lupin species. The main lupin species is *Lupinus angustifolius*, or narrow-leafed lupin, but *L. albus* (white lupin) and *L. luteus* (yellow lupin) are also grown. The first commercial variety of yellow lupins was released in 1997, so production is currently both very local and small. The other pulses are: dry peas (*Pisum sativum*), including duns, blues, marrowfat and others; faba (horse, or tic) beans (*Vicia faba)*; chickpeas (*Cicer arietinum*), both desi and kabuli types; and lentils (*Lens culinaris*), both red and green.

Some of these species are used both as food for both animals and humans. For example, both horse beans and broad beans are types of faba beans, and lupins, though mainly animal feed, are eaten in small quantities by people in many parts of the world, including Australia.

Markets and marketing issues

Over the last 30 years there has been a revolution in Australia in the production of cool season pulses. In 1967 we produced some 30,000 t of pulses, mainly dry peas, whereas in 1996 production had climbed to some 2.3 million tonnes, of which about 600,000 t were used in Australia. Table 1 gives 1995 production of pulses by species and State, and projected total production by species for the year 2005.

Despite a large immigrant population from southern Europe, the Middle East and Asia, all areas where pulses are an important part of the diet, Australia has one of the lowest levels of pulse consumption in the world. We consume, on average, 6 g/person/day. This is half the British average and only a fifth that consumed daily in India. Australians consume only about 40,000 t of pulses per year. One of the crucial changes needed to increase pulse consumption in Australia is to turn them into a convenience food (see later information on processing). Most of the Australian production retained here is used to feed farm animals in periods of shortage, is sold and turned into compound feeds for intensive animal industries or is used as seed in the following year. These uses accounted for the vast bulk (560,000 t) of 1995 production.

For the human market the key quality criteria are size, shape, colour, taste and cooking time.

The requirements vary between countries for the different pulses and thus there is a wide range of types of all pulses that are supplied into the marketplace. A good place to get some idea of the range is in a large health food shop.

Most of the lupins and some of the faba beans and dry peas produced in Australia are used as animal feed. Here the key factors are protein and energy levels, and price, related to animal nutritional requirements and least cost in rations. Australian lupins have a good reputation as a high quality product for animal feeds. They compete mainly against soya bean meal.

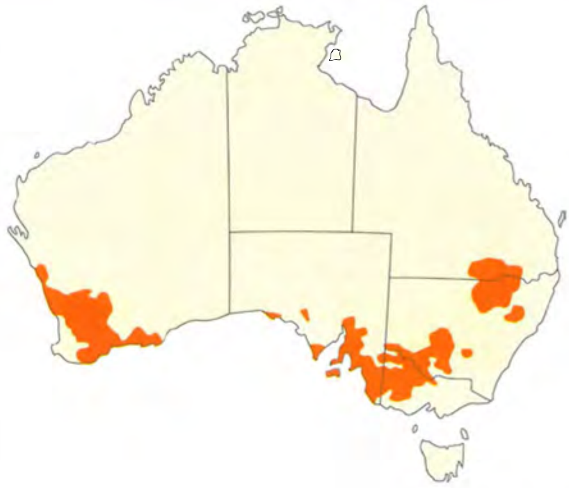
About the author

Adjunct Professor John Hamblin is Director of the Cooperative Research Centre for Legumes in Mediterranean Agriculture (CLIMA), The University of Western Australia, Nedlands, Western Australia 6907. He has worked mainly on pulses and cereals, both as a plant breeder and as an agronomist, in Australia (Adelaide, Horsham, Perth, Geraldton, Albany), the U.K. (Reading, Cambridge), and Syria (Aleppo).

Distribution of main current production of lupins

Distribution of main current production of field peas

Distribution of main current production of chickpeas



Distribution of main current production of faba beans

Distribution of main current production of lentils

Production requirements

The key production factor in determining whether a pulse will grow in a region is adaptation to soil pH. The scale runs from yellow lupins, the most acid tolerant (liking a low pH or acid soil), through narrow-leafed lupins to white lupins, peas, faba beans, chickpeas and lentils being the most acid sensitive (liking a high pH or alkaline soil).

No pulse is very tolerant of waterlogging. Faba beans and yellow lupins are the most tolerant and lentils the least. But all prefer free-draining soils, and yellow and narrow-leafed lupins are particularly well adapted to deep sands, whereas lentils, faba beans, chickpeas and peas are adapted to heavier soils.

Faba beans tend to need longer growing seasons, chickpea are intermediate, and peas and lentils do well in dry areas.

However, if waterlogging is not a problem, then provided the maturity of the chosen variety is suitable, all species will yield better in more favourable climates. On free-draining acid sands, yellow and narrow-leafed lupins will cope with a wide range of growing seasons, but high yields will be obtained only in favourable years.

Varieties

There are active breeding programs in Australia producing a series of new varieties for all seven species considered here and all the species are grown or are capable of being grown in the four southern mainland States. For this reason it is not sensible to make recommendations on specific varieties for different parts of this vast area. The best information for any particular area will be available from the nearest department of agriculture office, or a farm consultant or company agronomist. They have the local knowledge that is needed when making varietal decisions at a particular place.

However a few general principles to consider when choosing a variety are:

- does the species suit your soils,
- once you have decided on species look for varieties with a maturity that suits your local climate,
- then consider the market requirements
- find out what pests and diseases are likely to be locally important.

Chose your variety to meet your market specifications and for resistance or tolerance to likely local pests and diseases. Ask neighbours who have grown the species of interest, what problems they encountered, then choose a variety that minimises the risk of those problems.

Agronomy

Again it is not possible in the space available to consider in any detail the agronomy of seven species that are adapted to many States in Australia. This is because agronomy is location specific; weed species, for example, vary with soil type, climate and paddock history. The main factors that need to be considered and the information that must be obtained before growing a new crop include:

1) Seed source

a) likelihood of introducing weeds or seed-borne diseases

b) germination percentage—only use seed with a good germination percentage

c) does the seed need inoculating with rhizobium and lime pelleting to ensure good nitrogen fixation?

d) does the seed need any other form of seed dressing to control pests and/ or diseases?

2) Paddock history:

a) what is the likely weed spectrum and density?

b) is there a risk of disease carry over because of similar species being grown in the preceding year?

c) is a pre-planting herbicide needed, either a knock down or a residual?

d) what cultivation, if any, is needed before planting?

3) Planting

a) what seeding rate to use

b) what depth to plant

c) when to plant in relation to the break of the season and soil moisture and in relation to other crops in the planting program

d) what fertilisers to use and at what rate; should the fertiliser be placed with the seed or broadcast

Lentils with and without the appropriate rhizobium inoculum. Note the pale green nitrogen deficient plot on the right and the healthy, nitrogen fixing plot on the left. Photo courtesy Brett Thompson.

A range of pulses offered for sale in a supermarket in India.

The author, Adjunct Professor John Hamblin (right), inspects a faba bean crop at Merredin, WA.

e) should herbicides be applied at planting?

4) Growing season

a) what pests diseases and weeds are likely to occur, how do you control them and when is control economic?

b) try to determine why a crop grows well or poorly and use this information to improve performance in the future

5) Harvest

a) many legumes are difficult to harvest—make sure that you have the equipment that you need to ensure effective harvesting. There is no point in growing a magnificent crop if you leave most of it on the ground. Things to consider include extra fingers to reduce shake, modifications to the cutter bars, crop lifters and air blowers. You may consider windrowing

b) appropriate harvesting is vital for seed quality both for the market and for the next crop. Legume seed is very easily damaged at harvest because of the seed size and the way the growing points are joined to the cotyledons which are the seeds food reserves. Harvest with the concave as wide open as possible and the drum speed as slow as possible. For seed, harvest when there is a little moisture around (e.g. at night) as the seeds are less brittle and harvesting damage is reduced.

c) make sure the seed you keep for planting the next year is of the highest quality. Good quality seed sets up good crops.

6) After harvest

a) move seed as little as possible, augering damages seed

b) when augering make sure the auger runs full

c) do not store the seed if there is weed contamination, this is particularly important if the weeds are brassicas (radish, turnip etc) as they emit volatiles which can kill seed.

Cool season pulse production ('000 t) in Australia in 1995, and production predicted for 2005.

State	Crop					
	Lupins	Chick peas	Faba beans	Dry peas	Lentils	Total
New South Wales	110	40	21	23	0.3	148.3
Victoria	45	170	40	205	35	375
Queensland	0	8	0	0	0	40
Western Australia	1200	25	24	28	0.3	1210.3
Southern Australia	72	15	34	208	2.5	292.5
Australian total	1417	258	119	464	38.1	2296.1
Predicted tonnage in 2005 (Meyer 1994)	2150	490	250	900	20	3810

7) Rotations

a) as legumes can fix nitrogen they can improve the nutrition of following crops

b) legumes can be used to provide a weed and disease break for other crops, particularly cereals and oilseeds.

Pest and disease control

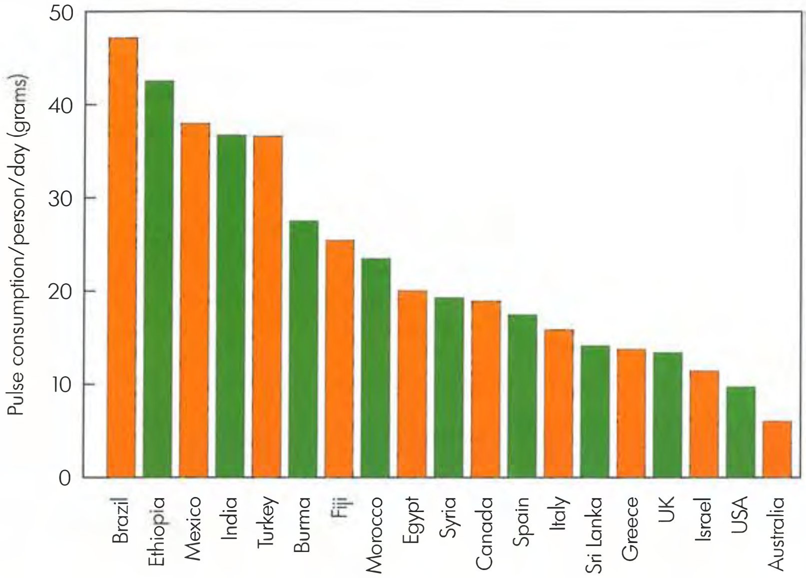
Legumes are particularly susceptible to pests and diseases because of the high protein levels in both the plant and the seeds, providing excellent nutrition for pests and diseases. Many of the pests and diseases of legumes have a double effect on the value of the crop: first, they reduce the yield potential and second, they often damage and blemish the seeds, so that the quality and value of the product is reduced.

The main pests and disease of pulses.

Pests and diseases	Lupins			Dry peas	Faba beans	Chick peas	Lentils
	narrow	white	yellow				
Insects							
Redlegged earth mite	x	x	xxx	xx	xx	ns	ns
Cutworms or brown pasture loopers	x	x	x	x	x	ns	x
Pea weevil	ns	ns	ns	xx	ns	ns	ns
Heliothis/Helicoverpa	xx	xxx	xxx	xxx	xxx	xxx	xxx
Lucerne flea	ns	ns	ns	ns	x	ns	xx
Aphids (feeding damage)	x	x	xxx	ns	x	ns	x
Virus diseases							
Bean yellow mosaic virus	xx	xx	xx	x	x	ns	x
Cucumber mosaic virus	xx	ns	xx	ns	ns	xx	xx
Lueteo viruses	ns	ns	ns	ns	xxx	xxx	xx
Pea seed-borne mosaic virus	ns	ns	ns	x	x	ns	xx
Alfalfa mosaic virus	ns	ns	ns	ns	ns	xx	xx
Fungal diseases							
Brown leaf spot	xxx	xxx	x	ns	ns	ns	ns
Pleiocheata root rot	xxx	xxx	ns	ns	ns	ns	ns
Rust	ns	ns	ns	ns	xx	ns	ns
Anthracnose	xxx	xxx	xxx	ns	ns	ns	ns
Ascochyta	ns	ns	ns	xxx	xxx	xxx	xxx
Powdery mildew	ns	ns	ns	xx	ns	ns	ns
Downy mildew	ns	ns	ns	xx	ns	ns	ns
Botrytis	x	x	x	ns	xxx	xx	ns
Sclerotinia	x	x	x	ns	x	xx	xx
Phomopsis	xx	x	xx	ns	ns	ns	ns

xxx = can be a major problem; xx = can be a problem; x = can be a minor problem; ns = either the problem is not significant or does not affect this species or the problem is not yet present in Australia or we lack knowledge.

This listing is not all inclusive, if you find a pest or disease that is not here, inform your local department of agriculture. Note some pests and diseases can be locally important but of less significance from a national perspective. My thanks to Mark Sweetingham, Roger Jones, Darryl Hardie and James Ridsdill-Smith for help in drafting this table.



Pulse consumption in various countries. Figure courtesy Nancy Longnecker; data from FAO Yearbook 1993.

The most likely pests and diseases of cool season pulses are listed by species in Table 2 (they are illustrated in PulsePak—see *Key references*). For many diseases and some pests, crop hygiene is the best way of minimising risk. This includes clean seed, an appropriate rotational break to reduce the carry over of soil-borne diseases, the use of seed dressings, appropriate agronomy (e.g. stubble retention to reduce rain splash for diseases that are splash dispersed), good plant nutrition so that plants are better able to resist disease, and regular monitoring to observe if and when problems arise. At this point remedial treatments may be possible, particularly the use of insecticides against common pests such as redlegged earth mite and Heliothis (now called Helicoverpa). The latter pest not only reduces yield by eating developing seeds, but also lowers quality by damaging more mature seeds.

There is considerable research interest in developing integrated pest management systems for pulses, and some are now available. Their components include, for example, the use of rotation, stubble retention, planting depth, seed dressing and improved varietal resistance to control brown leaf spot and Plietocheata root rot in narrow-leafed lupins. These integrated management systems, as they become more widespread, will have many benefits. The use of rotational and agronomic methods to minimise the level of attack by pests and diseases will reduce our reliance on chemical controls, increasing the useful life of pesticides and resistance genes, and enhancing our 'clean green' image.

It is likely that in the next 5–10 years genetic engineering will provide resistance to increasing numbers of pests and diseases. Already an alpha amylose gene from French beans has been inserted in peas to control pea weevils and virus resistance genes have been transferred to narrow-leafed and yellow lupins

Harvest and processing

Many pulses provide particular problems at harvest and special techniques have been developed to minimise harvest losses. They include air blowers to reduce the risk of pod shattering in lupins and crop lifters to help pick up peas that have lodged. Often considerable care is needed as many pulses have some (or many) pods close to the ground (lentils, chickpeas, faba beans) and the header speed needs to be slow to ensure it picks up the maximum number of pods without getting stones or stumps into the concave.

Pulse seeds are very sensitive to mishandling in harvesting, handling and storage. This is because the cotyledons, which are the major part of the seed and provide the reserves needed for the seed to germinate vigorously and grow well (and also are the main part that we eat) are attached to the root and shoot axis by very small and delicate attachments. If the harvesting, handling or storage is rough, or if the seed is too dry and brittle, then the attachments break and the growing points are separated from their food reserves. They are not able to grow. Ways of minimising damage include harvesting with the concave drum open as far as possible and the drum speed as low as possible. Also, harvesting at night, when there is some moisture in the atmosphere, makes the seed less brittle. When seed is being moved in augers, the augers should always be full. The seed should be moved as few times as possible to reduce the risk of damage.

The major form of processing of pulses is to split the seed and remove the seed coat (e.g. split peas and lentils). Also, the seeds may be ground to provide a flour for dhal and other dishes. If their use in Australia is to increase there is a need for the public to be aware of pulses, understand their value in the diet and know quick and tasty ways of preparing them. A limitation to their use is the need to pre-soak the seeds, often overnight, so there has to be forward planning in their use. A recent arrival on the market is a product called 'QuickPulse', which has been pre-soaked and partially cooked. It will be interesting to see if this approach makes pulses a more acceptable part of the everyday diet. Various tinned pulse products are also available.

In animal feeds, or if the pulse is used as a source of fibre or protein in the food industry, various separation techniques may be used, but these are not of great importance to the producer, except that his choice of variety and agronomic practice should maximise the industrial component if he is paid a premium for it (a rare event).

Economics of production

Like the agronomy, the economics of growing pulses are highly dependent on local factors. Thus, any comments must be very general. The first is start in a small way and learn about which species and varieties are best suited to your local soils and climate; make sure that market opportunities are there, and be well informed about the best production system for your area. It is only by maximising the yield of good quality product while controlling input costs that pulses can be grown profitably.

The rewards can be substantial, particularly when you remember that the benefits of growing a legume spillover into the crop that follows. Good weed control in the pulse crop reduces the carry over of root diseases and allows more timely planting of the following crop. This can lead to dramatic yield improvements in the following crop. The effect of lupins on the yield of following cereals in Western Australia is often an increase of 50% over the yield of cereals grown continuously. These effects can dramatically improve whole-farm income, even when the direct profit from the pulse is relatively small.

Key contacts

The key scientists in the development of new pulses are the plant breeders. They are mainly based in the State departments of agriculture. The target species are: lupins in Western Australia and New South Wales; peas in Victoria, South Australia and Western Australia; chickpeas in New South Wales, Victoria and Western Australia; and lentils in Victoria. Work on faba beans is based at the Waite Institute in the University of Adelaide. However, for local recommendations the district offices of State departments of agriculture, farm consultants and farmer suppliers such as the fertiliser, chemical, seed companies and pastoral houses are major sources of information.

Pulse Australia is the top industry body. Its address is P.O. Box R838 Royal Exchange Sydney, NSW 2000.

Key references

The best, most comprehensive and easily accessible source of information in Australia that distils the knowledge of many people on pulse production is a computer-based information package called 'PulsePak', developed initially by Agriculture WA and CLIMA. With a grant from the Grains Research and Development Corporation, and input from all State departments of agriculture it has been improved to provide national coverage and will be released across the country in September 1997. It includes further information on all the topics in this paper. PulsePak is available for $50 from CLIMA, The University of Western Australia, Nedlands, Western Australia 6907

The other key source of information are the farm notes, fact sheets etc. that many organisations, but particularly State departments of agriculture, produce on pulse crops with their jurisdiction.

Cowpea

Bruce Imrie

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is a highly variable annual legume species that originated in Africa. There are three recognised subspecific groups of cultivated cowpeas. Two of these are grown in Australia with most varieties grown for grain, forage and green manure being in the 'cowpea' group. The other type, the yardlong bean, is a minor vegetable.

Cowpeas vary in growth habit from erect or semi-erect types with short (<100 days) growth duration grown mostly for grain, to longer (>120 days) duration semi-erect to trailing plants grown primarily for forage. Cowpea is a minor crop in Australia, its main advantage being drought tolerance.

Cowpeas are grown as a green manure crop in coastal sugarcane areas, as a forage or dual purpose grain/forage crop in coastal and subcoastal southern Queensland, and as a grain crop from central Queensland to central NSW. Grain production is shown in Table 1 (the most recent published statistics).

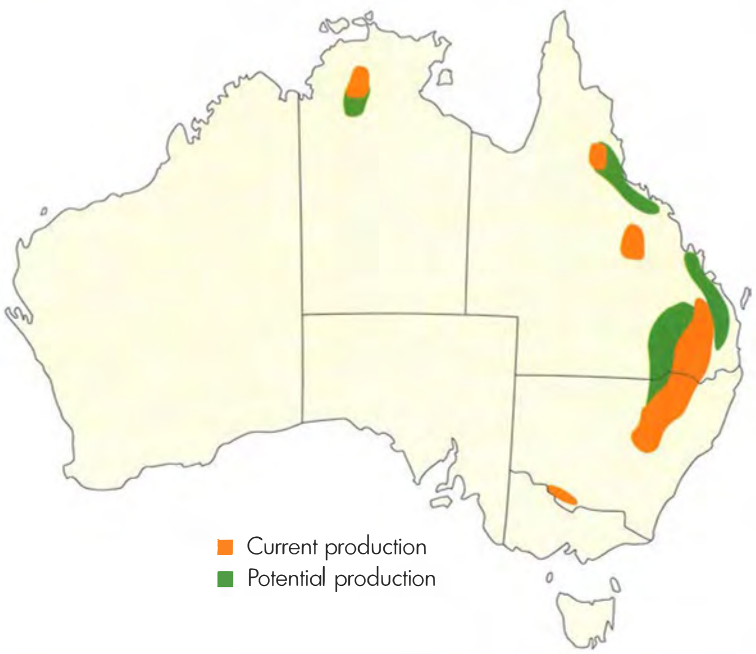
Worldwide production exceeds 2 million tonnes but only a small proportion enters international trade. The major production areas are Africa (Nigeria, Niger), Asia (India, Myanmar) and the Americas (USA, Brazil, West Indies). Of the developed countries, only the USA is a substantial producer and exporter. The predominant grain type traded is the 'blackeye pea', a large white seed with a black patch around the hilum, although markets exist for seed with a range of sizes and colours. Small red-seeded cowpeas are sometimes substituted for adzuki beans in Japan.

Production requirements

Cowpeas are grown on a wide range of soils but show a preference for sandy soils which are less restrictive of root growth. This adaptation to lighter soils is coupled with tolerance of drought through reduced leaf growth, reduced water loss through stomates, and leaf movement to reduce light and heat load when stressed. Conversely, cowpea has poor tolerance of waterlogging.

Cowpeas grow during summer. The base temperature for germination is 8.5°C and for leaf expansion is 20°C. The optimum temperature for growth and development is around 30°C.

Varieties vary in their response to day length, some being insensitive and flowering in 30 days after sowing when grown at a temperature around 30°C. Time of flowering of



photosensitive varieties is dependent on time and location of sowing and may be more than 100 days. Even in early flowering varieties, the flowering period can be extended by warm and moist conditions, leading to asynchronous maturity. The optimum sowing times are December in NSW and January in Queensland. Early-sown crops tend to have elongated internodes, are less erect, more vegetative and lower yielding than those sown at the optimum time.

Crop agronomy

Varieties selected for grain production in Australia are the more erect, short duration plant type (Table 2). Later maturing varieties such as Arafura, Ebony PR and Meringa are available for forage production.

For grain production, growers generally aim for a plant population of 200,000 to 300,000/ha requiring a seeding rate of about 60 kg/ha for Banjo, 50 kg/ha for Big Buff and 25 kg/ha for Red Caloona. Narrower rows (30–50 cm) are preferred to wider rows (70–100 cm), although the latter may be necessary in minimum-till farming systems.

Cowpeas are usually grown dryland rather than irrigated and fertiliser application depends on anticipated yield and soil fertility. As cowpea is a legume, it is not necessary to apply nitrogen but application of a phosphatic fertiliser at a rate of up to 20 kg P/ha is usually beneficial.

Annual grasses and some broadleaf weeds can be controlled by a presowing application of trifluralin which is the only herbicide registered for use on cowpea.

Table 1. Production of cowpea grain in Australia.

Year	Area (ha)	Production (t)
1987-88	10317	3730
1988-89	5981	2038
1989-90	3886	1717
1990-91	4578	1791
1991-92	9321	4423

Source: Australian Bureau of Statistics

Key messages

- Cowpea is a summer growing legume with diverse uses.
- Cowpea has greater drought tolerance than other pulses.
- Cowpea can be a valuable grain crop but requires good crop management to produce food grade product.

Cowpea in flower

Cowpea crop nearing maturity

Seed of common cowpea cultivars

Table 2. Grain cowpea varieties in Australia.

Variety	Days to flower	Days to maturity	Growth habit	Seed size (g/1000) and colour
Banjo	52	100	Erect/semi-erect	210, white with black eye.
Big Buff	49	105	Short, erect	180, buff to pinkish brown.
Holstein	49	100	Erect/semi-erect	190, black & white holstein pattern
Red Caloona (dual purpose)	52	105	Tall, erect	60, dark pink to red.

About the author

Dr Bruce Imrie is a Project Leader in CSIRO Tropical Agriculture, Brisbane (see *Key contacts* for address), where he has been a breeder of pulse and oilseed crops for more than 20 years.

Cowpea is very attractive to insects, particularly flower thrips, pod borers such as Heliothis, and sucking bugs such as green vegetable bug. Control by one or two applications of insecticide is invariably necessary. Failure to control insect pests could result in grain being downgraded from food quality to stockfeed and make production uneconomic. Bruchids may infest stored grain in subtropical and tropical regions.

The most important disease of cowpea is stem rot caused by *Phytophthora vignae*. This disease is common in the wetter coastal and subcoastal areas, and on heavier soils which may become waterlogged. Red Caloona, Ebony PR and Holstein have resistance to the most prevalent races of the pathogen at the time of writing but resistance might be expected to break down in the future.

Harvest and marketing

Cowpeas are direct harvested and header settings are critical to produce undamaged seed because cowpea seeds are large and easily split. They need to be harvested when seed moisture content is 14–16% using a low drum speed and open concave on the header.

Most crops are traded by members of the National Agricultural Commodities Marketing Association which has established standards for grain quality. Varieties Big Buff and Holstein are proprietary varieties protected by PBR and can be grown only under contract to the seed company licensee.

Economics

Costs of production are similar to those for mung bean. Returns are dependent on seed quality, being around $800 /t for food grade but dropping to $250/t or less for stockfeed. This dichotomy in pricing makes cowpeas more risky for growers than mung beans, the summer pulse alternative.

Key contacts

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Key references

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Guar

Rob Fletcher
Helen Murphy

Introduction

Guar or cluster bean (*Cyamopsis tetragonoloba*) is believed to have originated in Africa but has been grown throughout southern Asia since ancient times as a vegetable and fodder crop. The plant is variable in form, ranging from 0.5 to 3 metres in height. The degree of branching is variable, and this variability influences its end-use.

This crop is a drought-tolerant, warm-weather, deep-rooted summer-growing annual legume. It grows well in soils of low fertility in the arid and semi-arid areas of the tropics and sub-tropics where the rainfall is summer-dominant. The green pods can be consumed as vegetables by humans and the crop grazed by cattle. Guar is also useful for green manure.

Guar has been trialled over some years in central and south-eastern Queensland. This interest has arisen because of the vegetable gum (galactomannan) in the guar seed. Guar gum has multiple uses in thickening, stabilising, sizing and strengthening all kinds of materials in the food, paper, textile, mining, petroleum and pharmaceutical industries. It has exceptionally high viscosity at low concentration and its cold-water swelling can function over a wide range of pH.

After removal of the gum, the seed material can be used for stockfeed as it has a high protein content (35%), but the material needs treatment before feeding to monogastric animals since it contains anti-nutritional factors (a trypsin inhibitor, polyphenols, haemagglutinin and saponins). The good ground-cover this crop provides can be useful for soil conservation.

Guar is currently grown commercially in north-western India. eastern Pakistan and the United States.

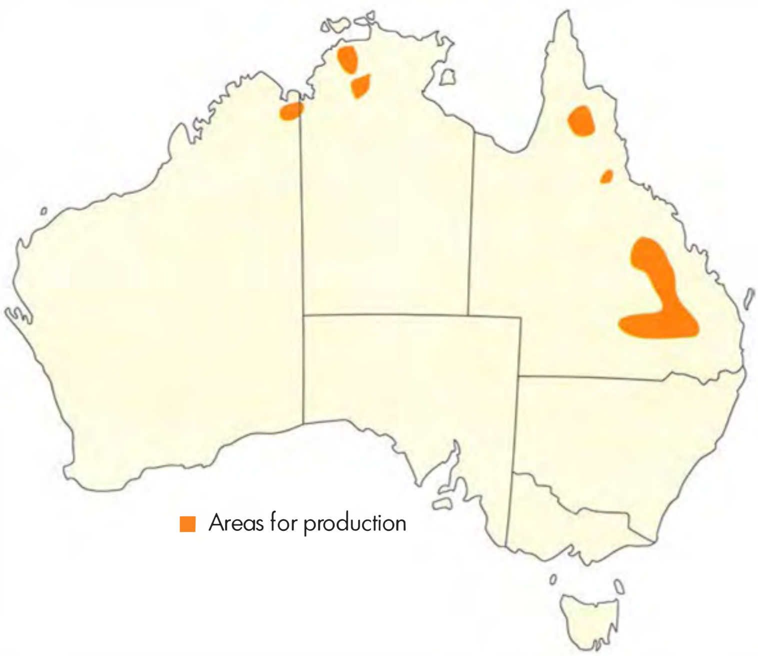
Markets and marketing issues

No crop of guar should be contemplated in Australia unless its end-use and price have been prearranged.

Seed yields of up to 4 t/ha have been achieved. Up to 35% gum yields have been produced, but this level is dependent on both variety and environment.

Production requirements

Guar can tolerate a wide range of climatic and soil conditions but maximum growth occurs at high temperatures (25–30°C). The



crop is intolerant of shade and must be frost-free for 110–130 days. Guar prefers lighter soils within the pH range 7.5–8, is very intolerant of water-logging, has a moderate level of salt tolerance and good drought tolerance.

Varieties/breeds

Approximately 400 lines of guar have been introduced into Australia and more than 100 of these have been included in field trials. The strongly-branching varieties Brooks and ECR67 and the sparsely-branching CP177 have been commonly used for research in Queensland.

Agronomy

The type of branching of the variety will influence its suitability for the end-use envisaged: branching varieties are considered more suited to seed production, and the single-stem varieties better suited to vegetable pod production.

Optimum row spacings depend on the branching ability of the variety, with branching varieties more suited to lower planting densities. Row spacings of 45–60 cm are usually effective and sowing rates of 11–28 kg/ha used when the crop is grown for seed. Higher sowing rates are required if the crop is to be grazed or cut for forage.

The recommended sowing time ranges from November to early January in Queensland. Guar has been termed a quantitative short-day plant and most varieties are indeterminant.

Cultivar/selections of guar differing in branching: (top left) CP177 (top right) IC 9203, (lower left) CP 177 S9, and (lower right) Brooks S36

CB756 has been found to be a suitable inoculum.

The most common nutrient deficiencies to be expected are zinc and phosphorus; this plant has a high phosphorus requirement.

Pest and disease control

Pod-sucking bug (*Riptorus serripes*) can cause some damage in guar, and diseases likely to be a problem are *Sclerotium rolfsii* and *Alternaria cucumerina*.

Key messages

If guar is grown as a commercial crop, the end-use and prices to be received should be pre-arranged.

Plots of guar growing at the University of Queensland Gatton College

About the authors

Dr Rob Fletcher lectures in crop improvement at the University of Queensland Gatton College. He has a special interest in the successful commercialisation of new crop industries.

Miss Helen Murphy is a former postgraduate student.

See *Key contacts* for the authors' address.

Harvest and processing

Most guar varieties reach maturity in 125–160 days. Normal harvesting machinery can be used but speeds need to be reduced to avoid damage to the seed. For storage, drying to at least 14% moisture is important.

Guar gum is located in a layer on the inner surface of the endosperm cell walls of the seed.

The gum is extracted by either a wet or dry processing method, neither of which is currently commercially available in Australia. The former method is more efficient and involves cleaning, boiling in $NaHCO_3$ and urea, washing, dehusking, drying, separation and grinding of the endosperm, suspension in isopropanol, heating, separation and drying, suspension in methanol, refluxing and drying.

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Lima beans

Robert Redden

Introduction

Lima beans *(Phaseolus lunatus)* are in the same plant genus as common, or navy, beans *(Phaseolus vulgaris),* to which they are distantly related. In Australia, lima beans are principally used as 'green baby lima beans' canned in brine either alone or as a component of 3–4 bean mixes for use in salads. They are also retailed direct to food consumers as raw beans in small 200 g–1 kg packages. Currently up to 1000 t/year are imported. No lima beans are commercially produced in Australia despite several years of research demonstrating the feasibility of such production.

Lima beans are imported as raw beans from the USA, where they are the by-product of harvesting immature 'wet' green beans which need to be immediately canned. Given the small scale of demand in Australia, such a specialised industry would not be feasible here. However, produced for dry grain, lima beans have yields comparable with navy beans and are more drought tolerant under rainfed growing conditions. Because of the extensive low branching of the bean bushes and indeterminate pod maturity on individual flower bearing stalks (vacemes), cutting and windrowing harvest techniques are required. Equipment for this is available in traditional navy and peanut areas such as the Burnett (Qld).

The major competitor for exports of 'green baby' lima is the USA, while Myanmar exports similar white seed types to Japan. Australian production, besides meeting local demand, could target Japan for high quality exports. Potential producers require skills in intensive crop management similar to those needed for navy beans.

Markets

Principal markets in Australia are: Simplot Edgells and Masterfoods canneries: and health food shops and other retail outlets for raw beans. Potential export markets included Japan and East Asia.

The market chain to canneries is from producers via an intermediate grading plant capable of meeting delivery specifications, such as Bean Growers Australia, Kingaroy. Most raw grain is distributed to retailers from importers who specialise in repacking bulk shipments, as do, for example, Ward McKenzie or Lee McKeon.

Prices for beans landed in Australia are based on world parity and associated fluctuations in a 10–20% range. Current price delivered to a cannery is about $1400/t.

Production requirements

Lima beans are a summer crop of 80–100 days duration, best suited to a 20–35°C range. The cropping zone of southern Queensland is suitable in the 600–1000 mm rainfall zone with a predominantly summer peak. With irrigation, the crop could be summer grown from central NSW to central Queensland and winter grown in north Queensland. The crop needs 300–400 mm of irrigation.

Lima beans are best suited to light, well-drained soils with deep profiles. Yields can be very constrained on some heavy black mulching clays.

Varieties

The emerging varieties suited to production in south Queensland and with acceptable canning quality include the 'Green baby' series, 'Improved Kingston' and 'Mendoza bush'.

Agronomy

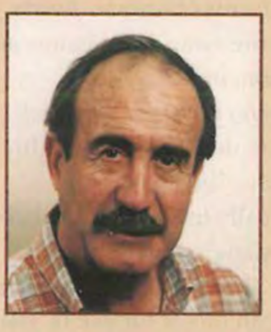
Lima beans can be drilled either into conventionally tilled seed beds or directly into minimum tillage stubble, using either row crop or conventional seed drills. 'Triflurilan' herbicide at recommended rates can be applied pre-emergence, while post-emergence weed control can be achieved with 'Basogram' and 'Stomp'.

For optimal yields, the potential crop nutrient requirement must be supplied as fertiliser: under rainfed conditions, 40 kg/ha of nitrogen for a 1 t/ha harvest; and up to 80 kg/ha for 2 t/ha irrigated crop.

The growth rate of lima beans is very temperature sensitive, with maturity delayed as minimum temperatures fall below 20°C. Due to indeterminacy in growth habit, the plants leaves often remain green and functional while pods mature, especially if moisture and temperature are favourable. The interval from planting to first ripe pod is in the range 80–100 days, with 1–2 weeks more for 50% ripe pods. In southern Queensland optimal sowing time is November–December, with some reduction in yield potential with either earlier or later plantings.

Trial plots of lima beans

About the author



Dr Robert Redden obtained BAgSc and MAgSc degrees in plant breeding at the University of Adelaide Waite campus. He obtained his PhD in plant breeding at Cornell University, USA, then had a two-year post-doctorate in the bread wheat program at CIMMYT before becoming a wheat specialist with IITA in Nigeria during 1975–77. He transferred to cowpea breeding at IITA during 1977–81, then moved to DPI Queensland in 1982 to work on breeding of *Phaseolus vulgaris*, particularly navy beans. The three new varieties of navy beans that were bred now account for over 70% of the industry output. See *Key contacts* for the author's address.

Pests and diseases

Diseases of lima beans are minor, with insignificant damage due to a bacterial 'chocolate spot' and to root rot fungi. Serious pests include myrids, thrips and *Helicoverpa* (*Heliothis*) spp. Myrids are very difficult to detect, since most of their life cycle is spent inside developing seed pods. Control will require targeting of adults with preventative insecticides before they lay their eggs, i.e. from early flowering.

Thrips and heliothis can be controlled, as for navy beans, with a range of insecticides including lannate, larvin, decamethrin and endosulphan at recommended rates.

Harvest

Although lima beans have seed pods with thick hard shells, they tend to split open along the inner suture, exposing seed to the weather and, at full maturity, tend to dehisce. Due to uneven ripening of pods over a 2–3 week period and non-ripening of up to 20% because of indeterminate flowering and partially developed pods, timing of harvest is problematic. The desired green coloration of seed is best expressed at point of maturity—seeds tend to be bleached white at full maturation. The best compromise appears to be harvest when pods are 30–50% mature, although immediate grading to remove green leafy trash is required to avoid growth of moulds on damp seed. Harvest trials with desiccants and different harvest timings are in progress. Yields may be reduced by up to 20% if the crop is harvested before 50% maturity.

A production trial of lima beans

Key statistics

Potential new crop but domestic demand is only about 1,000 t/year

Key messages

Canned salad beans, summer legume, drought tolerant

For marketing for human consumption, deliveries to grading facilities should have less than 5% trash/foreign matter. This should fall to zero after grading, which will also remove split and under-sized seed.

Economics

Gross margins under rainfed conditions in the Barnett region are likely to be at least 20% better for lima than for navy beans. Input costs for the two crops will be similar but yields and prices will be higher for lima beans.

At 0.74 t/ha, gross margins for navy beans are $207/ha. Lima beans are likely to yield at least 10% better on average and to be up to 30% better in price, although losses during grading to meet commercial specifications may exceed those for navy beans.

Establishment costs may be minimal for current peanut and navy bean growers who can use existing equipment for cutting and windrowing at harvest. However, for other growers specialised harvesting equipment will need to be purchased.

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Moth bean

Rob Fletcher
Glen Beech

Introduction

Moth bean (*Vigna aconitifolia*) comes from the semi-arid regions of the state of Rajasthan in north-western India where it is claimed to be the most drought-tolerant legume grown in the country. It may have potential as a summer-growing annual crop for central or southern Queensland or northern New South Wales in those areas too dry for mung beans.

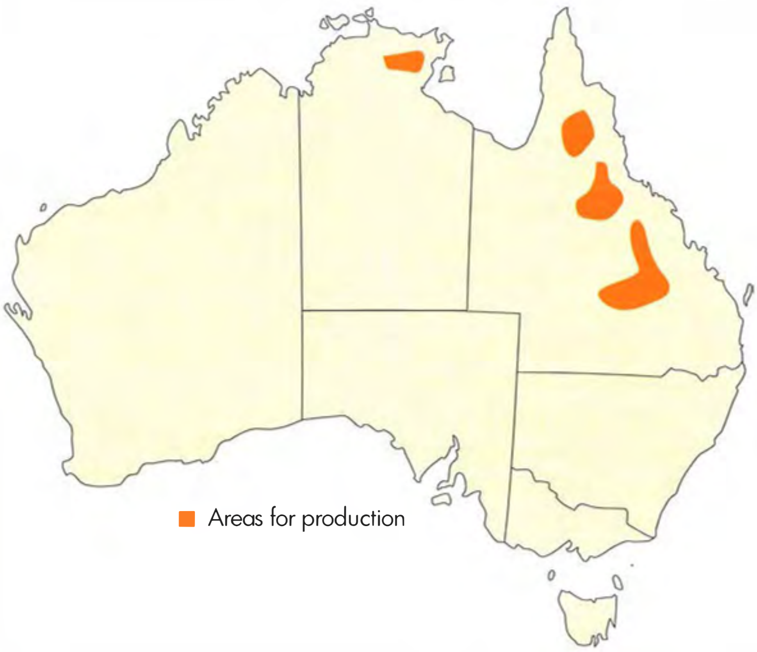
The drought tolerance of this bean may be due to the well developed tap root and/or the manner in which the plant produces a thick, low-lying mat, covering the soil surface and apparently reducing moisture loss. Such growth has advantages with erosion and weed control but presents difficulties with normal harvesting machinery since the inter-twined mat of material needs to be cut in strips so it can be harvested.

Moth bean seed is used as human food in India and Pakistan. The seed is cooked whole or split and the green pods can be cooked and eaten as vegetables. Seeds are also processed in dhal (a sprouted bean paste) or bhujia (a salted snack). The seed has 22–31% crude protein, with a biological value similar to that of mung bean but with lower digestibility.

Moth bean is currently grown in the north-western desert regions of India and Pakistan in those areas where mung beans may suffer from drought. This crop is also grown for seed in Myanmar, Sri Lanka, southern China, Thailand, Malaysia and southern Africa, and for fodder in the USA, in Texas and California. The only trials conducted in Australia to date have been initial seed trials.

Markets and marketing issues

Production of moth bean varies greatly within India, and all production is consumed within that country. No crop of moth bean should be contemplated in Australia unless its end-use and price have been prearranged. Average yields have ranged from 70–270 kg/ha, over areas ranging from 1.3–2.1 million ha. Experimental yields between 600 and 2600 kg/ha have been obtained in south-eastern Queensland.



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Dr Rob Fletcher lectures in crop improvement at the University of Queensland Gatton College. He has a special interest in the sucessful commercialisation of new crop industries.

Mr Glen Beech is a former postgraduate student.

See *Key contacts* for the authors' address.

Production requirements

Moth bean can grow well in hot climates with 500–750 mm of annual rainfall; if as little as 50–60 mm rainfall falls as three to four showers during the growing period, a good yield can be obtained. The crop does best on freely drained, light sandy soil and will not tolerate waterlogging. Initial vegetative development is slow and weeds at this stage of the crop's growth can smother the seedlings. Irrigation of moth bean is not recommended. Plants tolerate salinity and have been successfully nodulated over a wide pH range (3.5–10).

Varieties

The popular Indian variety Jadia (IPC MO 943; CPI 96934) was a satisfactory yielder in south-eastern Queensland in the 1992–93 summer. However, the best yielding variety in that season, and in other trials in the glasshouse, was IPC MO 950 (CPI 96943).

Because of differences in day length and temperature responses between varieties, overseas varieties may not be suitable for the Australian environment. At Gatton, moth bean has produced excessive vegetative growth, relative to the amount of seed eventually produced.

Agronomy

The land preparation required for moth bean is minimal. Standard machinery is satisfactory for sowing but care needs to be exercised with the use of press wheels behind sowing tynes. The low growth habit of the plant may render it impossible to gather with crop lifters if the plants are growing in furrows.

Planting rates of approximately 10 kg/ha, with 30–50 cm row spacings have proven most successful. Wider row spacings, with corresponding increase in the density of plants within the rows are desirable in drier areas, since the pods under these conditions tend to be carried on the tops of the plants. Moth beans have been intercropped with sorghum, millet or cotton in India.

In rotations, moth beans have been found to be of benefit to subsequent crops of millet. Low levels of fertiliser are applied to moth bean crops in India.

The best sowing time in south-eastern Queensland was between 15 December and 15 January. Maturity occurs 75–100 days after planting.

Pest and disease control

There are many diseases and pests which have been recorded in moth bean crops in India but they are rarely reported as causing serious losses, probably due to the environment in which is usually grown. Bean yellow mosaic leaf virus has been observed in trials in south-eastern Queensland, but losses were minor.

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Plants and seeds of four accessions of *Vigna aconitifolia.* From Top to Bottom, CPI 96943, CPI 50749, CPI 50750, CPI 106070. Plants were planted on the 31 January and photographed at 3 months.

Five cultivars of *Vigna aconitifolia* grown at the University of Queensland Gatton College.

Key message

Moth bean is currently not a commercial crop in Australia. If grown, it should be treated as an experimental crop. If grown as a commercial crop, its end-use and price should be pre-arranged.

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Mung bean

Bruce Imrie

Introduction

Mung bean (*Vigna radiata)* is a warm season annual pulse grown mostly as an opportunity crop in rotation with cereals. Mung beans are erect plants with few branches carrying pods borne in clusters near the top of the plant. Pods contain 8–15 green seeds. Its main advantages are that, being a legume, it does not require nitrogen fertiliser application, and it has a short (75–90 days) growth duration which means that it requires less water than many other crops and is easily fitted into rotations. Its main disadvantage is that it is difficult to produce premium grade seed that commands top market prices.

Production and trade

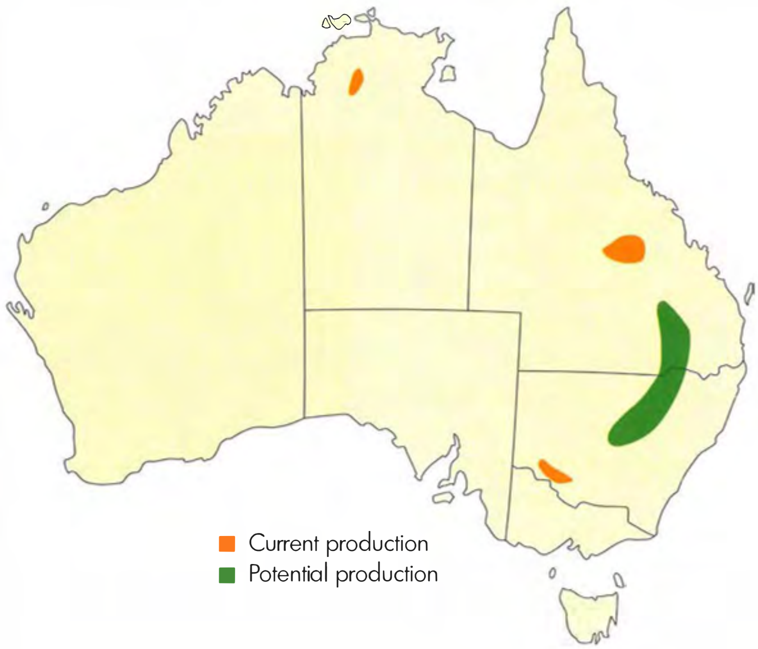
Mung beans are grown from the Northern Territory to southern NSW, with the bulk of production being in central and southern Queensland and northern NSW (Table 1). Most of the crop is exported, with the main destinations in recent years being Taiwan, the Philippines, the USA, and the U.K. (Table 2). The main producing countries are India, Indonesia, China, and Burma, while the largest importers are Japan, Europe, the USA and Taiwan.

Mung bean is an expanding crop in northern Australia as growers seek to diversify production and to take advantage of market opportunities opened up as production declines in some Asian countries where intensive horticultural production is replacing field crops.

Adaptation

Varieties of mung bean grown in Australia are day-length insensitive and can be sown at any time of the year provided the minimum temperature is above 15°C. The optimum temperature range for growth is 27–30°C which means that the crop is usually grown during the summer. Sowing time varies with location with the optimum period being early January in the Northern Territory and central Queensland, late December on the Darling Downs and northern NSW and early December in central and southern NSW. A dry harvest period is highly desirable as most varieties are very susceptible to weather damage caused by wet and humid conditions and leading to severe reduction of seed quality.

Mung beans will grow on most soils, with a preference for loams with a pH in the range 5.5–7.5. Root growth can be restricted on heavy clays, with a consequent limitation to growth. Mung beans do not tolerate saline soils.



Mung bean crop

Crop production and management

Mung bean crops are usually managed with the aim of producing premium grade seed. Critical to this objective is to ensure even ripening of the crop. This starts with the choice of a paddock with no variation in soil type and a smooth surface with no sticks, stones, or low spots. There should be at least 60 cm water in the profile at sowing.

Planting seed must be a pure line, preferably with high vigour. A seeding rate to achieve a plant population of 200–350 thousand plants/ha dryland and 400 thousand plants/ha under irrigation is recommended. The crop is sown at different row spacings from 18–100 cm depending on yield expectations, planting equipment, stubble management and rotated crops. When there is a full profile at sowing or when the crop is to be irrigated, and a high yield is expected, narrower rows are preferred. However, many irrigated crops are sown on ridges or beds spaced for other species and mung beans are similarly sown in wide rows. Frequently, twin rows, rather than a single row, are sown on ridges to achieve a higher plant population. Narrow rows and high populations are desirable for late sowings to achieve some compensation for the yield limitation due to small plant size. Crops grown in a minimum or no-till system are grown in wide rows which are also chosen when yield expectation is low due to dry conditions.

About the author

Dr Bruce Imrie is a Project Leader in CSIRO Tropical Agriculture in Brisbane (see *Key contacts* for address) where he has been a breeder of mung beans and other crops for more than 20 years.

Varieties available and their characteristics are shown in Table 3.

Nitrogen fertiliser is usually not applied but it is advisable to use Rhizobium inoculum on the seed, particularly when the crop is to be grown in a paddock that has not been sown to mung beans for several years. Phosphate fertiliser

Mung bean seed

is usually required at 5–10 kg P/ha on dryland crops and 10–20 kg P/ha on irrigated crops. Higher rates may be required if the crop is grown after a long fallow when VAM levels decline, or on severely P deficient soils. Mung beans are also sensitive to zinc deficiency which can be corrected by a soil application of zinc sulphate monohydrate pre-sowing or a foliar spray of zinc sulphate heptahydrate.

Key messages

Mungbean is a high value pulse crop with a short growth duration that fits into many crop rotations.

A high standard of crop management, conducted under a HACCP quality assurance program is required to produce premium grade beans.

The crop is well serviced and promoted by an active industry association.

Weed control reduces competition during growth and improves yields but, more importantly, the presence of weed seeds in the harvested crop can cause the seed to be downgraded in quality. Grain sorghum, cereal and thornapple seeds are extremely difficult to grade out of mung beans and their occurrence is not tolerated in premium grade seed. Several herbicides are registered for use on mung bean, including both pre-and post-emergence herbicides for control of grasses and broadleaf weeds. Advice on suitable herbicides can be obtained from local traders and/or chemical companies.

Mung beans are frequently grown under irrigation. Because of their short growth duration they need less water than many other crops, and their high value produces good returns per megalitre of water applied. Since mung beans are sensitive to waterlogging, laser-levelled paddocks with a relatively steep grade are preferred. Water should be applied quickly and tailwater drained away. The most critical time for irrigation is during flowering and early podfill. It is essential to manage irrigation carefully to provide sufficient water to fill pods but not so much that maturity is delayed and uneven.

Insect pest control is also important to achieve high seed quality. The following are the main insect pests of mung bean.

- Green mirids and thrips which are flower feeders and cause flower and pod abortion leading to yield reduction and uneven maturity.

Irrigated mung beans

Basic quality standards for export mung beans (1996)

Premium sprouting: Bright even green, 99% pure with no other seeds, minimum 94% germination, maximum 6% hard seeds and 7% oversoaks. No charcoal rot.

No. 1 sprouting: Bright green, 99% pure with up to 0.3% other seeds, minimum 90% germination, maximum 10% hard seeds and 10% oversoaks. No charcoal rot.

Cooking: Bright green, 99% pure with up to 0.3% other seeds. There are no germination standards.

Processing: Colour not up to cooking standard, 98% pure with up to 2% other seeds. There are no germination standards.

Colour is checked against standard samples.

Table 1. Area and production of mung beans in Australia.

	NSW	Queensland	Australia
Area (' 000 ha)			
1991-92	3.7	30.3	34.0
1992-93	7.0	25.0	32.0
1993-94	7.0	14.0	21.0
1994-95	7.3	21.7	29.0
1995-96	10.0	35.0	45.0
Production (kt)			
1991-92	3.2	16.8	20.0
1992-93	5.0	10.0	15.0
1993-94	7.0	20.0	27.0
1994-95	2.9	9.7	12.6
1995-96	8.0	8.0	16.0

Source: Australian Commodity Statistics 1996.

Table 2. Amounts of mung beans (t) exported to the main destination countries for Australian product.

	1993-94	1994-95	1995-96
Philippines	1956	6468	6655
Taiwan	3646	2645	4361
USA	1145	1278	1078
UK	901	1661	1312
Europe	856	826	1196

Source: Australian Bureau of Statistics.

- Heliothis and *Maruca* caterpillars which feed in flowers and on developing pods. They can cause a large reduction in both seed yield and quality.
- Bugs such as the green vegetable bug, red banded shield bug, pod sucking bug and brown bean bug which stick their proboscis into pods and seeds and cause various levels of damage depending on the stage of growth of seeds at the time of attack. Bug 'stings' on seeds are often the cause of oversoaks, seeds that have rapid imbibition of water during the sprouting process.

Chemical control involving one or two sprays is usually necessary but care is needed in choice of insecticide and the time of application to achieve maximum effectiveness. Many growers employ a bug checker to monitor crops and advise on control measures.

A serious postharvest pest is the bruchid beetle (*Callobruchus maculatus*) which can infest the crop in the field before harvest, then develop during storage. Stored infested grain can be completely destroyed if not fumigated. This pest is prevalent in tropical areas northwards from central Queensland.

Mung beans are susceptible to diseases caused by fungi, bacteria and viruses but their effects are usually not severe in the growing crop. Seedling loss sometimes occurs due to Sclerotinia, particularly in stressed crops sown into cereal stubble. Various leaf and stem pathogens such as powdery mildew and bacterial blight are frequently seen but do not cause much damage. Powdery mildew is usually seen late in the life of a crop and is of little consequence in crops sown at the optimum time but can cause significant damage to spring sown crops or those sown late in summer. Gummy pod, caused by a bacterium, is most frequently seen in crops under stress and generally a low proportion of plants are affected. The most serious disease of stressed plants is tan spot caused by *Curtobacterium flaccumfaciens*, which mostly causes a leaf spot, but when infection is severe, systemic symptoms of stunting and poor pod and seed set occur.

The most important disease of mung bean is charcoal rot caused by the fungal pathogen *Macrophomina phaseolina*. Charcoal rot normally has little effect on growing plants but is an important problem for bean sprouters, and infection precludes seed lots being classified sprouting grade. The causal organism is extremely widespread in cropping soils, and attacks a range of species. In some years most mung bean crops can be affected.

Harvest and marketing

Mung bean is a specialised food crop used for production of bean sprouts, or cooked as whole beans and dhal, while mung bean flour is used for making noodles and a wide range of traditional Asian foods. Mung bean growers are being encouraged to adopt a HACCP quality assurance plan to satisfy the needs of buyers.

Harvest occurs when more than 95% of pods are mature and dry. Harvesting too early results in the loss of immature pods while harvesting too late can also result in losses as pods are shaken from the plant during the harvest operation. A desiccant is often used to kill green leaf and the few remaining green pods before harvest, particularly in spring sown crops or when high soil-water content slows maturation. Beans are easily split or damaged during heading but this can be minimised by harvesting at the correct seed moisture content (14–16%), avoiding harvest during the middle of the day, and careful attention to header settings. Small cracks in the seed coat that are not readily visible can occur with incorrect header settings or rough handling and can cause downgrading of a seed lot due to a high oversoak level. Many growers employ a harvesting contractor who specialises in mung bean.

Following harvest, beans are trucked to a grading shed where they are cleaned, graded and bagged as soon as possible. The graded seed is sampled for quality evaluation by an accredited laboratory and, following classification, a sample is usually given to an exporter who arranges a sale. It has been common practice for exporters to sell on sample but the establishment of quality grades has resulted in an increasing number of seed lots being sold on description. A recent innovation has been the sale of crops in bulk for dhal production. This is an option for growers who can see at the time of harvest that their crop will be classified processing grade.

Table 3. Mung bean varieties grown in Australia.

Variety	Seed colour/lustre	Seed size g/100	Comments
Berken	Green/shiny	6.0	Standard sprouting bean, susceptible to all diseases and weather damage.
Celera	Green/shiny	3.5	Older variety with high hard seed content. Used mainly for processing.
Black Pearl	Black/shiny	6.0	Proprietary variety similar to Berken.
Emerald	Green/shiny	6.5	Hard seeded, used mainly for cooking/processing. High yielding.
Satin	Green/dull	5.7	Weather tolerant. Produces high sprout yield.
Putland	Green/shiny	4.5	Photoperiod sensitive variety suited only to tropical areas (NT).
Delta	Green/shiny	6.8	High yielding sprouting bean but weather susceptible.
Green Diamond	Green/shiny	4.5	Hard seeded, used mainly for processing. Tolerates dry conditions.

Table 4. Gross economic margins for mung beans grown on the Darling Downs in Queensland.

Item	Dryland fallow crop	Dryland double crop	Irrigated crop
Expected price ($/t on farm)	420	420	420
Expected yield (t/ha)	0.8	0.6	1.5
Expected Income ($/ha)	336	252	630
Variable costs ($/ha)	122	113	129
Gross margin ($/ha)	214	139	501

Economics

Mung beans are a valuable field crop, both in terms of dollar returns and in their contribution to total farm income as a leguminous rotation crop. Estimates of gross economic margins for production on the Darling Downs are presented in Table 4. The expected price is an average of returns from the various grades. In recent years, premium grade sprouting beans have been valued above $700/t, No. 1 sprouting grade and cooking beans above $600/t, and processing grade $400/t.

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Sesame seed

Mal Bennett

Introduction

Sesame, *Sesamum indicum* L., is an ancient oil crop supplying seeds for confectionery purposes, edible oil, paste (tahini), cake and flour. It is typically a crop of small farmers in the developing countries. In 1993, all but 1000 ha of the about 7 million ha of sesame grown were in developing countries (Table 1).

Sesame has important agricultural attributes: it is adapted to tropical and temperate conditions, grows well on stored soil moisture with minimal irrigation or rainfall, can produce good yields under high temperatures, and its grain has a high value ($A1000/t).

Sesame world production areas have remained generally stable over the years, but in some countries the crop is being marginalised. Competition from more remunerative crops and a shortage of labour have pushed sesame to the less fertile fields and to areas of higher risk. Left unchecked, sesame production may decrease in the foreseeable future. This provides an opportunity for Australia to produce larger quantities of high quality sesame seed to replace 'lost' world production.

However, before sesame can realise its potential, extensive research is needed to adapt the crop to mechanical agricultural systems. Furthermore, as Australia is becoming more involved with Asian regional activities, where much of the world's sesame is grown, Australia's own agricultural self-interest could be combined with its international extension and aid programs by taking the lead in a regional sesame research and development project.

Markets and marketing issues

In 1993, the world trade in sesame seed was 486,000 t. Japan was the largest importer taking 24% of the world imports. The second largest importer was the USA with 8% of world imports. It is forecast that the imports of sesame seed will grow at between 6 and 8% per annum until the year 2012.

Australia imported 6400 t of sesame seed in 1996 (worth $A12.7m), with China, Mexico and India the main suppliers. Australian sesame seed production is centred in the Northern Territory and Queensland, with New South Wales showing interest. Although production has fallen from 291 t in 1988–89 to 90 t in 1993–94, it is anticipated that improvements in cultivars and harvesting technology will increase production.

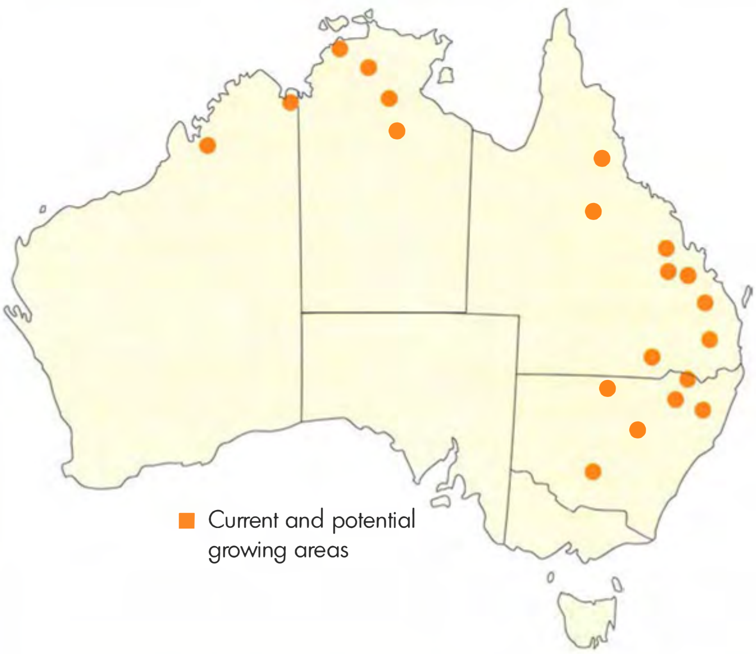

Table 1. Sesame areas, production and yields in 1993 by region.

Region or country	Harvested area ('000 ha)	Production ('000 t)	Yield (kg/ha)
World			
Total	6172	2491	404
Developed countries	1	3	644
Developing countries	6943	2432	350
Regions			
America	296	169	571
Asia	4549	1841	405
Africa	1326	480	362
Major producers			
Mexico	90	50	556
India	2400	800	333
Myanmar	992	237	239
China	580	500	862
Nigeria	200	50	250
Sudan	525	120	229
Uganda	150	75	500

Source: FAO Production Yearbook, Vol. 47, 1994

There is an obvious potential to develop markets for Australian sesame seed, both here and overseas. Sesame seed is presently imported into Australia either as a whole seed and then dehulled or imported dehulled.

Oil industry. Australia imported 769 t of sesame oil and sesame products in 1996 (worth $A3.7m). Currently, there is one sesame oil processor in Australia producing small quantities of sesame oil from locally grown seed.

Confectionery and biscuit industry. The raw seeds currently used in Australia for confectionery and biscuit production are sourced from local and overseas suppliers.

Tahini industry. Tahini, a traditional Middle Eastern sesame paste, is made from hulled sesame seed. Market demand is currently met by local manufacturers and imports from Mexico, the Middle East and some Mediterranean countries.

Dip and spread manufacturers. Dip manufacturers add ingredients, such as chickpeas and egg plant, to tahini and call the products Hommus and Baba Gannouj. These manufacturers purchase their tahini from local suppliers and some also use imports.

Bakery industry. The bakery industry prefers dehulled seeds, which are purchased from local and overseas suppliers.

Halva industry. Halva is a popular sweet made by mixing approximately 50% tahini with boiled/whipped sugar and several other ingredients to a manufacturer's recipe. At present all halva sold in Australia is fully imported from Greece, Turkey and Israel.

Attention to two aspects—natural antioxidants and organic sesame—could improve marketing of Australian sesame seed.

About the author

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Sesame seed contains antioxidants which inhibit the development of rancidity in the oil. In the food industry, where synthetic antioxidants are used extensively, there is an increasing demand for more natural products.

With the growing demand for organically grown food there is a market for sesame products produced under organic conditions.

Crop potential. During the 1970–80s Australian agronomists targeted chickpea and canola in their search for new commercial crops. Now, almost two decades later, chickpeas and canola are grown extensively, with domestic and international sales. Sesame has the potential to follow their development pattern with adequate research and persistence by scientists and farmers.

Production requirements

Sesame grows best on well-drained soils of moderate fertility. The optimum pH for growth ranges from 5.4 to 6.7. Good drainage is crucial, as sesame is very susceptible to short periods of waterlogging. Sesame is intolerant of very acidic or saline soils.

The response of sesame to both temperature and daylength indicates that it is well adapted to wet season production in the tropics, or summer production in the warmer temperate areas. While there is some variation between cultivars, the base temperature for germination is about 16°C. In temperate areas, soil temperatures determine the earliest date of sowing. The optimum temperature for growth varies with cultivar in the range 27–35°C. Periods of high temperature above 40°C during flowering reduce capsule and seed development.

Key messages

- Suitable to sorghum growing regions.
- High value oilseed crop.
- Extensive local and overseas markets.

Because sesame is short day plant, with flowering initiated as daylength declines to a critical level, cultivars are developed for particular latitudes.

The total amount of water required to grow a sesame crop ranges from 600 to 1000 mm, depending on the cultivar and the climatic conditions. The water requirement can be met from available soil moisture at sowing, rainfall during the growing season and irrigation.

Hail and frost cause severe damage to sesame crops. Strong winds as the crop matures will greatly increase the likelihood of lodging and pre-harvest seed losses.

Desiccation is a prerequisite to successful harvesting of sesame.

Cultivars

Four sesame cultivars are recommended for use in a Australia. They are 'Yori 77' and 'Edith' for the NT and northern WA, and 'Aussie Gold' and 'Beech's Choice' for Queensland. The characteristics of these four cultivars are given in Table 2. There are no cultivars recommended for growing in NSW and it is advised that prospective growers seek advice from Selected Seeds Pty Ltd, Qld.

Agronomy

There are various advantages in including sesame in a crop rotation system. If sown after a leguminous crop, sesame can utilise the residual nitrogen. If the leguminous crop made good growth, then the residual nitrogen should meet about one-third to one-half of the sesame crop needs.

Where sesame is rotated with a cereal, there can be mutual benefits in weed control. Broadleaf weeds can be readily controlled in the cereal crop using selective herbicides, such as atrazine or 2–4 D, greatly reducing the risk of broadleaf weeds in the subsequent sesame crop. Similarly, grass weeds which are difficult to control in the cereal crop can be fairly easily controlled in a conventionally tilled sesame crop using pre-emergent herbicides such as Treflan®, Dual® and Stomp®. Eptam® can be used as a pre-emergent herbicide for the control of some broadleaf weeds.

Paddocks to be sown should have an even grade and be well drained. As control of broadleaf weeds is a problem in sesame, paddocks with a low content of broadleaf weed seeds should be chosen.

The optimum sowing date for sesame in NSW is the first half of December, in Queensland the 2nd and 3rd weeks of December while in the NT the 2nd and 3rd weeks of January are recommended.

Seed should be sown in rows 30–50 cm apart to give 30–35 plants/m^2. Generally a sowing rate of 3.3 kg/ha of seed is required. If sesame is sown on 1 m row spacing to fit with equipment configuration or irrigation bed arrangement, then the seeding rate should be reduced by half. Sowing in cool conditions in NSW will require higher sowing rates.

As sesame seed is small, sowing depth should be no greater than 2.5 cm and the seed should be sown into moist soil.

The fertiliser requirements for sesame will depend on the fertility of the soil, which will, in turn, vary with soil type and previous land use. The following is a guide on the type and rate of fertiliser to be applied.

An application rate of 60 kg/ha of nitrogen is likely to be adequate. The nitrogen should all be applied at sowing as there appears to be no advantage in a split application.

Table 2. Characteristics of Australian sesame cultivars.

Characters	Queensland			Northern Territory	
	'Magwe Brown'	'Aussie Gold'	'Beech's Choice'	'Yori 77'	'Edith'
Seed yield (t/ha)	0.8	1.0	1.0	1.1	1.5
Seed size (g/1000)	2.6	3.3	2.9	3.0	3.2
Oil content (%)	54	50	54	54	54
Plant height (cm)	80	94	88	116	119
Branches/ plant	4.2	3.8	4.2	1.5	0.1
Capsules/ leaf axil	1	1	1	3	3
Days to flower	36	36	40	46	42

Most sandy loam soils can be expected to be deficient in P, K, S, Cu, Zn and B. Unless the area has received prior applications of fertiliser, an application of at least 100 kg/ha of both single superphosphate plus trace elements and muriate of potash is warranted.

The clay soils tend to be more fertile. They do not require K, but applications of P, S, Cu, Zn and B will be needed.

The number and timing of irrigations will depend on soil type, location and seasonal conditions. Generally, the crop requirements for water can be expected to be about half of that for cotton or maize. The preferred method for establishment is an initial watering before sowing. The soil needs to be kept moist until the beginning of flowering, to help early growth and to maintain herbicide activity. The most critical time for moisture is between first flower and completion of flowering. The final irrigation should be applied when the lower capsules turn yellow.

Pest and disease control

Sesame grows slowly during the early stages of growth and is not strongly competitive with weeds. Poor weed control early in the life of the crop can result in greatly reduced crop yields.

In the NT, zero-tillage techniques are recommended to assist establishment. Zero tillage involves sowing the crop into a mulch which reduces weed growth and has other benefits. These include reducing soil temperatures and soil surface evaporation, and protecting the soil from erosion. No post-emergence herbicides for grass control can be used.

In NSW, where row spacing is wide, inter-row cultivation and spot spraying with glyphosate is possible. The pre-emergent herbicides trifluralin, metolachlor, and pendimethalin can be used for control of grassy weeds. Sesame is extremely sensitive to low concentrations of the residual herbicides in the sulfonylurea family which arc widely used in wheat and barley.

Key statistics

Areas and production of sesame in Australia

Year	Northern Territory		Southern Queensland		New South Wales	
	Area (ha)	Production (t)	Area (ha)	Production (t)	Area (ha)	Production (t)
1990–91	420	90	18	7	–	–
1991–92	198	58	38	41	–	–
1992–93	130	49	55	17	30	13
1993–94	120	26	185	63	–	–
1994–95	120	44	150	45	–	–

These include Glean®, Logran® and various products containing metsulfuron such as Ally®. Growers should observe the plant-back periods listed on the label. The control of broadleaf weeds poses a major problem at the present time as no effective post-emergent herbicides have been identified.

While a wide range of insect pests attacks sesame around the world only the sesame leaf webber *(Antigastra catalaunalis)*, Heliothis caterpillars, *Helicoverpa punctigera* and *H. armigera* and green vegetable bug *(Nezara viridula)* have caused serious problems in Australia. To date, sesame leaf webber has not been recorded in NSW. Mirids can also infest sesame crops. The yellow mirid is a beneficial and should not be sprayed, while the green mirid may require control.

Heliothis caterpillars are highly mobile and can rapidly damage sesame capsules. Control is made difficult by the high levels of pesticide resistance found in Heliothis. Regular monitoring and the application of integrated pest management strategies are essential to minimise their impact. Similar pest management strategies to those used for cotton are recommended. The threshold level for spraying is one small to medium sized caterpillar per 10 plants. To date two applications of insecticide have provided satisfactory control.

Sesame is prone to root and stem diseases associated with waterlogging, while damping-off diseases can also occur if humidity is high. Seven diseases affecting sesame have been identified but only two of them, *Corynespora cassilcola* (target spot) and *Pseudocercospora sesami* (large cercospora leaf spot), can severely affect grain yields.

Large cercospora leaf spot causes large, irregularly shaped, dull brown spots on the foliage. The spots often coalesce, killing portions or entire leaves on susceptible cultivars during humid conditions.

Target spot first appears as dark (often purplish) spots on leaves, stems and pods. As spots enlarge they develop lighter coloured centres.

Harvesting, storage and handling

The indeterminate growth habit of sesame with its subsequent uneven ripening of the capsules creates difficulties for mechanical harvesting. However, techniques have now been developed that reduce seed losses during harvesting to less than 10%. It is important that the crop be completely dry before harvesting, as sap from green material passing through the header can discolour and taint the seed, creating off-flavours in subsequent processed products.

Commercial sesame cultivars grown in north-western Australia include 'Edith' (right) and 'Yori 77' (left).

The recommended procedure for harvesting sesame is to spray the crop with a desiccant when at least 70% of the capsules have changed colour from dark green to light green or yellow. In northern Australia, an aerial application of Reglone® at 1 L/ha has proven effective. In NSW and southern Queensland the rate of Reglone should be increased to 2–3 L/ha. In southern NSW where temperatures are much cooler, desiccants have proven unreliable and it is recommended that the crop be harvested and windrowed to dry.

The crop is harvested when 95% of the capsules have turned brown, which should be about 7–9 days after desiccation. At this stage, the grain moisture content will be about 6–7% in northern Australia. In temperate areas the moisture content is likely to be higher and the grain will require a longer time to dry before harvesting.

Harvesting is most efficient at a ground speed of 4–6 km/hour using a harvester fitted with a Harvestair® air reel and an extended table which gives a knife-to-auger distance as large as possible.

Sesame seed is easily threshed and relatively delicate, so drum speed should be reduced to about half of that required for cereals, and the concave clearance made as wide as possible. Seed damage during harvesting affects both the viability of the seed, storage and the quality of the oil.

For safe long-term storage, sesame seed should be clean, have a moisture content no more than 6% and be stored at a relative humidity of approximately 50% and at a temperature less than 18°C.

Economics of sesame production

The economics of sesame production will vary with location, while the attractiveness of the crop to a potential grower will depend on the expected returns from alternative crops that can be grown. The area sown to sesame is dependent on the area that can be harvested in 3 days by one harvester. Currently 90–100 ha is the recommended 'unit' area. A smaller area should be sown if the crop is being sown for the first time.

Gross margin budget for sesame production in the Northern Territory, Queensland and New South Wales

Item	NT	Qld Dryland [a]	Qld Irrigated [a]	NSW Dryland	NSW Irrigated
Income					
0.50 t @ $1000/t		500			
0.75 t @ $1000/t				750	
0.85 t @ $1000/t	850				850
1.00 t @ $1000/t			1000		
Freight subsidy	19				
A. Total income	$869	$500	$1000	$750	$850
Variable costs					
Channel maintenance	–	–	–	–	6
Land preparation	37[b]	15	15	21	34
Sowing and seed	12	14	14	12	13
Irrigation	–	–	132	–	85
Fertiliser	108	55	100	55	85
Weed control	–	35	35	36	49
Insect control	46	25	25	111	128
Desiccation	64	38	38	44	44
Harvesting	20	6	6	50	50
Cartage, cleaning and handling	95	–	–	73	78
B. Total variable costs	$382	$188	$365	$402	$572
Gross margin (A – B) $/ha	**$487**	**$312**	**$635**	**$348**	**$278**

[a] Seed is sold at the farm gate
[b] Zero tillage and land preparation

Plant breeding is developing higher yielding cultivars for the sesame growing regions of Australia.

Acknowledgments

This paper has been largely prepared from papers presented at the First Australian Sesame Conference held at Darwin and Katherine in 1995 and the (Australian) Sesame Growers Guide. The assistance of Dr Bruce Imrie and Mr Brett Clift is particularly acknowledged for editing this paper

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Medicinal Herbs

Medicinal herbs

Peter Purbrick

Introduction

Herbal medicine and natural pharmaceuticals are moving from fringe to mainstream, with greater numbers of people seeking remedies and health approaches free of the side-effects caused by synthesised chemicals. This is now considered one of the most vital and high growth industries of the 90s and is set to expand even further into the next century.

This trend for the increasing acceptance of herbal medicines in Australia is well supported by trends around the world. In Germany and France which together represent 39% of the $14 billion global retail market (*Nutrition Business Journal*), herbal remedies known as phytotherapeutics are well established, with the costs for therapeutic use covered by health insurance systems, and the quality criteria applied to regulation and manufacturing comparable to those for chemical drugs.

Markets and marketing issues

The crude botanical raw materials for this industry have long been grown and traded in many countries around the world. As the Australian market for herbal medicine develops, opportunities are arising for raw materials to be grown in Australia, both for the local and export markets. Access to export markets may be facilitated by the 'clean green' image that Australian agriculture presents to the world.

Botanical raw materials are comprised of dried plant materials in the form of roots, barks, herbs, flowers, fruits, seeds, and resins. These materials are traded in a whole form or, more commonly, are cut and sifted to a consistently even particle size.

Market prices for raw botanical materials are usually determined by supply and demand, but generally tend to be stable.

Most traded European materials are priced at source in the range of $2.00 to $6.00/kg. Prices for certified organic produce can be anywhere between $10.00 and $30.00/kg. This supply market is very limited, hence the high prices. Prices for difficult-to-grow, wild-harvested, or certified organic materials, usually North American botanicals, can range in price from $20.00 to $120.00/kg.

The principal primary market for these raw materials is to industry which manufactures:

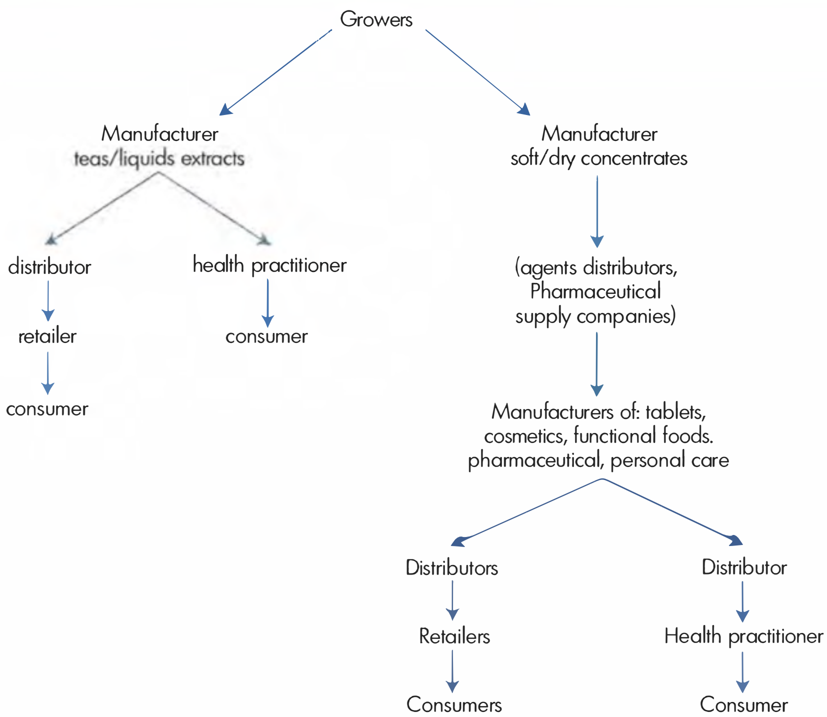
- essential oils
- liquid extracts and tinctures
- herbal teas
- concentrated soft extracts (for further industrial application)
- concentrated dry extracts (for further industrial application)
- plant-derived pure pharmaceutical drugs.

There are currently at least seven Australian manufacturers with the capacity to produce herbal extracts from crude botanicals, one manufacturer able to produce concentrated dry extracts, and five tablet manufacturers producing herbal tablets.

The figure on the following page simply illustrates the market chain which is characteristic of this industry.

Market size. The *global retail market* for herbal medicines is valued at US$14 billion (1997) as shown in the table below: (*Nutrition Business Journal* Jan/Feb 1997).

Country	(US$ billion 1997)
North America	1.54
Germany and France	5.46
Rest of Europe	1.68
Japan	2.38
Asia	2.66
Other	0.28
Total	**US$14 billion**



Annual growth by region

Country	Growth		Forecast 1993–
	1985–91	1991–92	
N. America	10%	12%	15%
EEC	10%	5%	8%
Rest of Europe	12%	8%	12%
Japan	18%	15%	15%
SE Asia	15%	12%	12%
India and Pakistan	12%	15%	15%

There are at least eight major European manufacturers, one of whom processes 4500 t of raw dried botanical material per year.

Australia

Estimate of the current herbal medicine market (1996–97).

Manufacturer	$40m
Importer	$40–50m
Retailers	$160–200m

Production requirements

Most medicinal herbs from Europe of North America will do best in temperate climatic regions. Within a climatic region there will be an optimum microclimate site for a particular plant species.

Medicinal herbs generally do best in moderate to highly fertile, light-textured soils with good moisture retention and drainage. Heavy soils may be acceptable for some herb crops but tend to be unsuitable for most root crops because of the extra difficulty (and hence the cost) in harvesting and cleaning.

The various geographical and climatic regions in Australia will offer the growing conditions required by most medicinal plant species in demand, although almost everywhere in Australia herb production will need irrigation. Certain herb crops may be unsuitable for summer growing in some areas because of heat, lack of rain or, conversely, the intensity of summer rain.

Agronomy

In general the market requires that medicinal plants test negative for any residues of pesticides, herbicides, heavy metals or radioactive contamination. Regular testing

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for such residues is routinely undertaken by manufacturers.

To achieve this there is a high demand for medicinal herbs produced under an organic-crop production system or at least a system with minimal use of chemicals.

Harvest and handling

The quality requirements in the acceptance process of all plant materials for therapeutic use are controlled by the Australian Therapeutic Goods Administration (TGA) through the Code of Good Manufacturing Practice. The three key standards against which raw materials are assessed are:

Identification—through macroscopic and microscopic examination of plant parts, organoleptic assessment (appearance, odour and taste) and chemical fingerprint analysis through Thin Layer Chromatography (TLC) or High Performance Liquid Chromatography (HPLC);

Purity—assessed against four standards: the presence of extraneous materials; an assessment that the material is sufficiently dry (if it is supposed to be dry material); the presence of any microbial contamination, in the form of pathogens, yeasts and moulds or aflatoxins; and the detection of any residues (herbicides, pesticides, heavy metals or radiation); and

> **Key statistics**
>
> Global retail market valued at $14 billion (1997)

Potency—the presence of a required level of active chemical constituents is determined by TLC, HPLC, Gas Chromatography and Mass Spectrophotometry.

To ensure that botanical raw materials for therapeutic use meet with these specifications the Code of GMP requires all suppliers of raw materials to meet conditions of supply which typically cover some of the following areas:

Identification. A Certificate of Identity must be supplied for each product with the material identified by botanical name, plant part and batch number. All product supplied must be identified by this same batch number.

Samples. Any purchase will depend on acceptance of a fully representative pre-shipment sample. All material supplied must be from the same batch as the sample, and conform with the analysis results of the sample.

Extraneous material. There must be no extraneous animal material

Medicinal herb products are a growing market in Australia and around the world.

or soil. Dead leaves and other plant material should be excluded. The tolerance limit for organic/inorganic extraneous materials is 1% by weight.

Drying. Plant material must be shade or indoor dried, with a maximum drying temperature of 45°C. The temperature must not exceed 35°C for herbs containing essential oils. There must be no mould or fungal growth during the drying process. Material is considered dry after the moisture content is 8–10%. At this point leaves will crumble when rubbed and stems will snap when bent.

Packing. Items should preferably be packed into new clean, lined, woven poly bags.

Comminution. Depending on the specification, herbs may be supplied in whole form, cut and sifted (to remove fine dust), or rubbed through various coarse screens to remove woody stalks.

Status. Where applicable, certification of organic farming practices should be supplied. Produce supplied from new organic suppliers is always checked for pesticide residues. Where herbs are grown using chemicals, details of chemicals used are required. Wild-crafted herbs are checked for pesticide residues and must meet other acceptance criteria e.g. suitability of the harvest location.

Economics of herb growing

The economics of medicinal herb production varies with the species. To take *Echinacea purpurea* as an example, at a planting rate of 50,000 plants/ha, a yield of 1.2–2.0 t/ha dried root may be achievable, based on dry root mass per plant of 20–40 g, in the second season. Flowering tops, harvested in the first season, may yield up to 5.0 t/ha, based on dry plant mass of 100 g/plant.

The Queensland DPI has recently prepared a draft discussion paper *Echinacea—a Commercial Overview.* In this paper the total costs of production for Echinacea were assessed at over $14,000/ha. This figure was arrived at after considering input costs for land preparation, mulch and irrigation, planting, fertiliser, weeding, harvesting and drying.

Echinacea purpurea

Marigold (*Calendula officinalis*)

Popular and emerging medicinal herbs

Common name	Botanical name	Part used	Currently grown in Australia	Potential for growing in Australia
Astragalus	*Astragalus membranace*	Root	✔	✔
Black Cohosh	*Cimicifuga racemosa*	Root		✔
Blue Flag	*Iris versicolor*	Root	✔	
Chamomile	*Matricaria recutita*	Flower	✔	✔
Chaste Tree	*Vitex agnus castus*	Fruit	✔	
Clivers	*Galium aparine*	Herb	✔	
Dandelion Root	*Taraxacum officinale*	Root	✔	
Echinacea	*Echinacea angustifolia*	Root	✔	
Echinacea	*Echinacea purpurea*	Root/Flowering	✔	
Golden Seal	*Hydrastis canadensis*	Root/Rhizome	✔	✔
Gotu Kola	*Centella asiatica*	Herb		✔
Licorice	*Glycyrrhiza glabra*	Root	✔	
Meadowsweet	*Filipendula ulmaria*	Herb	✔	
Passionfower	*Passiflora incarnata*	Herb	✔	
Red Clover	*Trifolium pratense*	Flower	✔	
St Mary's Thistle	*Silybum marianum (carduus)*	Seed	✔	✔
Valerian	*Valeriana officinalis*	Root	✔	
Wild Yam	*Dioscorea villosa*	Root/Rhizome		✔
Sage	*Salvia officinalis*	Leaf	✔	
Andrographis	*Andrographis panniculata*	Herb		✔
Small Willow Herb	*Epilobium parviflorum*	Herb		✔
Marshmallow Root	*Althea officinalis*	Root	✔	
Burdock	*Arctium lappa*	Root	✔	
Calendula	*Calendula officinalis*	Flower	✔	
Greater Celandine	*Chelidonium majus*	Leaf/Stem		
Hawthorn Berries	*Crataegus spp.*	Berry/Leaf/Flower	✔	
Globe artichoke	*Cynara scolymus*	Leaf	✔	
Euphorbia	*Euphorbia hirta*	Leaf/Stem		✔
Gentian	*Gentiana lutea*	Root		✔
St Johns Wort	*Hypericum perforatum*	Flowering herb	✔	
Elecampane	*Inula helenium*	Root	✔	
Motherwort	*Leonurus cardiaca*	Herb	✔	
White Horehound	*Marrubium vulgare*	Herb	✔	
Peppermint	*Mentha piperita*	Leaf	✔	
Yellow Dock	*Rumex crispus*	Root	✔	
Elder Flowers	*Sambucus nigra*	Flower	✔	
Skullcap	*Scutellaria laterifolia*	Herb	✔	
Saw Palmetto	*Serenoa serrulata*	Berry/Fruit		
Golden Rod	*Solidago virgaurea*	Herb		✔
Thyme	*Thymus vulgaris*	Leaf	✔	
Nettles	*Urtica dioica*	Leaf	✔	
Mullein	*Verbascum thapsus*	Leaf	✔	
Vervain	*Verbena officinalis*	Herb	✔	
Bacopa	*Bacopa monniera*	Herb		✔

Key messages

- Strong growth forecast for herbal medicines into the 21st century
- Well defined quality parameters for herbal raw materials
- Opportunities for Australian primary producers

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For further information see Australian Herb Industry Resource Guide.

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Woodward, Penny *An Australian Herbal* Hyland House

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Richardson, Brian *Licorice—A Commercial Overview* (Draft) Queensland Department of Primary Industry (Rural Parnership Unit)

Ginseng

Charlene Hosemans

Introduction

Opportunities and challenges for Australian ginseng production have been demonstrated in forest floor gardens at Gembrook, Victoria since early 1985. Organic, aged roots from these gardens are exported, and are also part of a retail product for Australian sales. Although many new trial gardens have commenced in Australia since late 1992, the only available data for current production are from the Gembrook gardens.

Ginseng, known as an 'adaptogen', helps to restore the balance in the pituitary gland which, in turn, encourages the system to cure itself. Research shows *Panax ginseng* (Asian) has a hot acid action while *Panax quinquefolius* (American) performs in a cool or alkaline way. Generally speaking, ginseng grown on the forest floor is more medicinally potent than that from intensive field cultivation.

Recorded Australian imports of ginseng exceed 14 t/year, with an estimated value of $8 million. There are further estimates that 5 times this amount may be entering the country undeclared. The increasing consumption of ginseng in Australia is the result of the rising proportion of the population of Asian origin and heavier demands for natural health products in society in general.

With wild ginseng stocks from Asia and North America diminishing, plus growing demands for better quality, chemical-free products, there is clearly potential for Australian commercial ginseng production, as an export commodity and for import replacement.

Growers need patience and commitment to achieve results with this long-term crop.

Markets and marketing issues

Ginseng is traded by weight as dried or fresh whole roots, with different prices paid for approximately 40 market grades. Some 95% of all ginseng production is consumed in Asia. In major Asian and Japanese centres American ginseng is the preferred choice. The Koreans prefer their own product. As little was available or known about American ginseng until recently, Asian ginseng has dominated Australian markets.

Little private trading occurs in China or Korea although this should change with new government regulations. Trading in North America takes place at the farm gate, although co-operative or network marketing is becoming popular there. This type of marketing is being considered by Australian growers. Successful profits can also be made by growers who manufacture and market retail products.

One Australian grower sells fresh and dried, 7-year-old American type whole roots to Singapore. Sales are based on the Wild American price plus 20%. It is estimated that other Australian growers will harvest from 2000 onwards.

Singapore buyers are keen to purchase more Australian-grown ginseng to satisfy client demands for top quality roots.

Market trends are best assessed from North American information. Similar information from China and Korea is difficult to correlate. In 1996, North American production exceeded 2500 t at prices that ranged from $60/kg for Artificial Shade 4-year old-roots to $1600/kg for Wild American roots. Oriental production dwarfs the North American production but prices start at $15/kg with no records for wild ginseng.

Production requirements

Ginseng will not grow in the sun. It requires 80–90% density shade, either artificial or natural; a nitrogen poor soil which can range in structure from sandy to heavy clayey loam; an acid soil with pH between 4.5 and 7; and a climate with four distinct seasons to encourage the plants to progress through their cycle in order to reach maturity. A cold winter is required for stimulation of the root to encourage the following years growth. A good rule of thumb is, 'grow ginseng with apples, not with bananas'. While the plants can survive hot summer days, they do not cope well with high humidity. Tropical or sub-tropical climates are not suitable. (See attached map with current trial areas showing some success.)

Ginseng is not a heavy drinker but requires a well-drained soil which needs to be kept moist and cool. In times of adversity, ginseng is known to withstand droughts better than floods. Land on river flats subject to flooding, or at the bottom of potentially wet gullies would not be suitable. If required, ground level drip irrigation is better than overhead systems.

Ginseng production requires 80–90% shade, either natural or artificial.

About the author

Charlene Hosemans is Managing Director, Gembrook Organic Ginseng Pty Ltd (see *Key contacts* for address), a Director of Austral-Asian Ginseng Pty Ltd, and Foundation Secretary of the Australian Ginseng Growers Assoc. Inc. She has made presentation on ginseng at a number of recent national and international conferences including: IGC'94, Vancouver, B.C., Canada; ICG'95, Harbin, China; New Crops Conference, Gatton 1996; and New Zealand Ginseng Seminars, July 1997

Ginseng production in raised beds under artificial shade

Normally unproductive steep slopes and/or forest floor areas where shade is so dense little else grows, can be quite suitable. Easterly or southerly aspects are generally preferable to north- or west-facing land. Beds should be raised to ensure good drainage.

Varieties/breeds

Ginseng *(Panax* spp.) belongs to the Araliaceae family, and is a slow maturing, woodland plant native to Asia and North America. From 11 known ginsengs, the two species with greatest medicinal and commercial value are *Panax ginseng* C.A.Meyer (native to Asia and sold as Chinese, Asian or Korean ginseng), and *Panax quinquefolius* L. (native to North America and sold as American or Canadian ginseng).

Both types are under cultivation in Australia, with the estimated ratio being 80% American and 20% Asian.

Australian-grown seed is not yet available for purchase. New gardens are planted with imported seed and/or Australian grown 1-year-old rootlets.

Many attempts worldwide have been made to clone ginseng, but none so far has succeeded. Ginseng research including tissue culture is being undertaken at the Gatton Campus of the University of Queensland. Results are not yet available.

Agronomy

There are three cultivation methods recognised: artificial shade, woods grown and wild simulated. Each growing method produces different results and consequently different market prices. Approximately 95% of the world's ginseng production occurs under artificial shade. Wild simulated is the cheapest growing method and produces the highest returns per dried weight yield.

Ginseng production—costs

Description of item	1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr
Seed – 20 kg @ $550 per kilo	$11000				
Shade cloth – 2000 ¥1.8m @ $3 per metre	$6000				
Treated posts	$2000				
Wire & miscellaneous hardware	$250				
Soaker hoses – 2 per bed @ $12 each	$2400				
Mulch – 300 bales 1st Yr @ $2 per bale	$600				
Mulch – top up 50 bales per annum @ $2		$100	$100	$100	$100
Fungicide (copper oxychloride)	$15	$15	$20	$20	$25
Soil improvers	$300	$300	$350	$350	$400
Sub totals	**$22565**	**$415**	**$470**	**$470**	**$525**
Possible total expenses			**$24445**		

Ginseng production—income

Description of Item	1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr
Seed sales @ $650/kg Grown 45 kg (100 lb) – Sold 22.5 kg (50 lb)			$14625		
Seed sales @ $600/kg Grown 136 kg (300 lb) – Sold 90 kg (200 lb)				$54000	
Seed sales @ $550/kg Grown 136 kg (300 lb) – Sold 90 kg (200 lb)					$49500
Root sales – 908 kg (2000 lb) @$160 per kg					$145280
Sub totals			$14625	$54000	$194780
Possible total income					$263,405

Soil testing for pH and nutrient levels should be done as part of site selection and bed preparation. Minimal tillage should be employed whenever possible. No tillage is used with wild simulated planting. Planting space should be free of debris and weeds, and beds should be raised to provide good drainage. Beds should run down slopes, not across them. Normal farm tilling machinery may be used in open ground. Most site preparation in a forest setting is carried out manually with normal garden implements, although some small mechanical devices may be useful, taking into consideration obstruction from trees and their roots.

Key statistics

- Imports = ca 15 t; exports = ca 10 kg (to May 1997)
- 900 growers are in their first and second years with trial plots often containing fewer than 1000 seeds or 100 root stocks
- 200 trials are in their third year, with some sites being less than 0.1 ha (0.25 acres)
- The total area of Australian trials was approximately 80 ha (200 acres) to January 1997. Another 40 ha (100 acres) is expected to be planted in spring 1997
- About 80% of plantings are of American ginseng and 20% of the Asian species.

Imported seeds are planted in spring/early summer. Australian grown seeds are planted in late autumn/winter. After planting, mulch is applied to conserve moisture and to protect the plants from hard frosts. If shade structures are being used, frames should be erected but covering is not required until seed has germinated. To prevent damage by heavy snow, shade covers may be removed during winter. If required, install irrigation systems after planting.

The plants are fully deciduous perennials with dieback in autumn and new growth each spring as the natural cycle.

Weeding, re-mulching and addition of soil conditioners are part of winter maintenance. Application of fertilisers should be minimal to ensure better value crops. New beds for planting can be prepared in advance at any time. Apart from site preparation, planting, harvesting and drying time, approximately 100 hours per annum for each hectare of forest cultivation is required for maintenance. Artificial shade maintenance can require less time if it is mechanised.

Plants reach maturity during their fourth or fifth year under artificial shade and after six or more years when grown under trees.

Key messages

- Patience is a must
- Quality before quantity
- Never fast—never easy
- Grow with a conscience — grow green
- Slow but sure = good returns

Fred Hosemans—ginseng industry champion

Fred Hosemans is the 'industry champion' for ginseng in Australia. In early 1985 he planted out his first 1/10th acre with American seed imported from North Carolina. Because of his patience and dogged persistence over the next 5–6 years, his crop was eventually established and Fred felt he had found a potential new crop for this country.

Fred's ginseng gardens, located on three farms around Gembrook in Victoria, now cover more than 2.5 ha (6 acres). His top quality ginseng roots, sold as both fresh and dried weight, are bringing excellent prices on the export market into Singapore. Some of his crop is also sold as dried powder on the Australian market.

In 1994, Fred was elected Foundation President of the Australian Ginseng Growers Association. Through his quarterly column in the Association's newsletter, Fred gives seasonal advice on crop maintenance. He and the other councillors devote a great deal of time to planning market strategies, such as crop validation and co-operative market structures.

After 13 seasons in his own garden, Fred is still Australia's most excited advocate of ginseng's potential to be a number one money earner for this country.

Fred and his wife Charlene have set out to teach other interested people how to grow ginseng in Australia, through annual seminars, their book, 'Ginseng Growing in Australia', by talking at agricultural field days, and by helping people who contact them. Charlene concentrates on medicinal and market knowledge, while Fred has perfected seed stratification and rootstock production and supplies new growers with quality planting materials.

Fred is showing everyone how to grow ginseng so that Australia will produce top quality, chemical-free ginseng and be recognised as a leader in the international ginseng market place.

Pest and disease control

Potential pathogens including *Rhizoctonia* spp., *Fusarium* spp. and *Pythium* spp. can destroy young plants. Although soil fumigation or chemical treatments are available, the majority of Australian growers prefer organic methods. Growers should be mindful that chemical treatments have the potential to leave residue on the roots, causing a reduction in market price. More importantly, natural therapies should not contain synthetic substances. Intensive planting in a monoculture garden can leave plants weak and more susceptible to disease. Less intensive plantings generally allow better air circulation and reduce the risk of foliar transfer of fungal problems.

With approx 70% of gardens in virgin bush soil where beneficial fungi appears to provide the appropriate mycorrhizal action required for healthy growth, there is little evidence of fungal disease being a major hurdle in Australia. Similarly, forest floor gardens have not yet experienced any problems with pests.

Trials in previously cultivated or grazed soils have not been as trouble free. Various treatments have been applied to infestations of reticulate slugs *(Deroceras reticulatum)*, cockchafers *(Adoryphorus couloni* and *Aphodius* spp.), chevron cutworm *(Diarsia intermixta)* and corbies *(Oncopera* spp.*)* with mixed success. Rather than straw, 'scratchy" mulches, such as rice hulls mixed with coarse sawdust, can be a deterrent, especially for slugs.

Animals such as rabbits, kangaroos, wallabies and wombats are deterred by fencing. Protecting ripe berries with netting prevents parrots from destroying seed production. Anchoring wire mesh firmly across the surface of planted areas prevents lyre bird problems.

Mature ginseng plants with ripe berries for seed production

Harvest and processing

Where planted grounds do not freeze, harvesting of the roots can take place throughout the dormant period, otherwise, all harvesting must be completed before the freeze occurs. Harvesting can be done either by hand or by mechanical methods, again depending on the chosen growing method. Mechanical harvest is done with modified potato or bulb diggers. After harvest, roots are sorted, removing damaged or spoiled roots to avoid a reduction in sale price.

For dried root sales, each days harvest is washed, loaded onto mesh trays and placed on the bottom rack in the drying area. Each successive days harvest is added at the bottom level with previous trays moved up in sequence Roots can be air dried in a temperature controlled heated building or in a kiln if quantities are larger. Dried roots are stored and transported in cardboard barrels and require dry atmosphere storage. Correctly dried roots can be stored indefinitely.

Fresh roots need to be harvested as close to sale as possible. They are washed and re-packed in a growing medium, such as peat moss, for transportation. Fresh roots are stored under refrigeration and are marketable only during the dormant period.

Security measures should be taken to guard against theft of harvested, stored and transported roots.

Ginseng products need to comply with the Australian *Therapeutic Goods Act* (TGA) and must be manufactured and sold under special Australia List numbers (AustL No). TGA licensed consultants can prepare a listing application for approval, although it is possible to do it yourself. Once TGA has granted the AustL No, it must appear on all packaging of the product.

Under the *Convention on International Trade in Endangered Species* (CITES) the U.S. government has listed *Panax quinquefolius* on Schedule 2.

The table below gives the numbers of trial ginseng growers in Australia by State as at January 1997. It is estimated that approximately 70% of all trials are being undertaken in forest-floor situations and, interestingly, more than 60% of these trials are managed by women. About 80% of the new growers have indicated an interest in growing their crop organically.

Growing season[b] 96/97	Qld	NSW	VIC	TAS	SA	WA	Total
1st year	31	126	309	10	23	14	513
2nd year	28	88	264	6	28	9	423
3rd year	16	23	81	41	7	45	213
4th year	7	11	64	58	4	26	170
10 years and over			1				1
Totals	82	248	719	115	62	94	1320

a These figures represent the trial growers known to the authors. Figures from unconfirmed reports of other ginseng plantings in various locations are not included here.

b Growing season means seed germination in spring 1996.

Two kg of 7-year-old ginseng roots produced at Gembrook

Therefore, a CITES Permit needs to be obtained from Australian Wildlife Protection before any whole root product is exported, even though the roots are cultivated in Australia. This rule does not apply to export of *Panax ginseng*.

Economics of production

The formula for *expenses* (Table 1) uses a site comprising 100 beds, 18 m long by 1.5 m wide, which have been planted intensively (50 × 150 mm spacings) with 20 kg of seed. Shade is erected singly over each bed on a structure of posts and wire. The cost of the shade is listed as a total expense but should last for three successive crops. Mulch is spread at the rate of 3 bales per bed. Soaker hoses are used for irrigation and use of fungicides and soil additives is minimal. Costs for land, rates etc., machinery and tools are not included.

Projected *income* (Table 2) is based on the anticipated sale of varying quantities of surplus seed from the end of the third growing season, plus the income from a yield of organically grown dried roots at the end of 5 years. Seed sales are calculated on the possible yield, amount kept for own use and consequent surplus sold. The price obtained for seed is expected to fall as more Australian grown seed becomes available. The production of seed for own use will reduce set-up costs for successive years and should be taken into account for any planning budgets. A harvest of 908 kg (2000 lb) of dried roots is considered to be a good average, with an excellent crop being about 1589 kg (3500 lb). Some crops yield less than 908 kg per 0.4 hectare (approx. 1 acre).

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Jojoba

Peter Milthorpe

Introduction

Jojoba (*Simmondsia chinensis*), pronounced ho-Ho-baa, produces a unique oil (or liquid wax) which has great potential for use in cosmetics and industrial applications. The oil is crushed from peanut-sized seeds that are produced from plantations of hedge-row grown shrubs. This desert plant is extremely drought tolerant, and is well suited to a broad area of inland Australia where it offers not only stable production, but environmental benefits not offered by existing land-use practices. These will ameliorate some of our land degradation problems.

Jojoba oil has many attributes that make it highly attractive to the cosmetic and skin-care industry. Not only does the oil have very acceptable skin-feel properties and excellent moisturising ability, but also it is very stable and gives products a long shelf life.

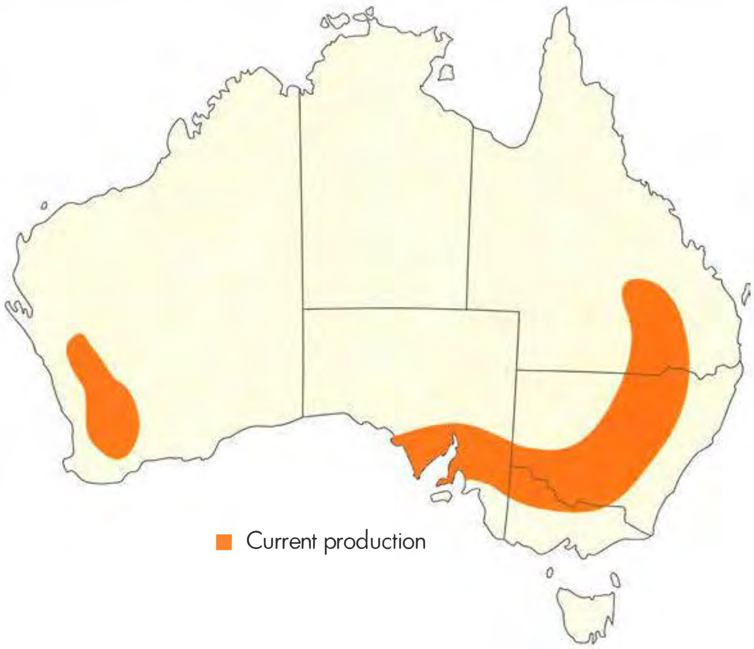
The industry in Australia is now based on the use of high-yielding cloned varieties especially selected for our climate, but as the majority of stands have been planted only since 1993 production is just commencing.

Although other countries has grown jojoba for some time, their industry is based mainly on the use of 'seeded' material and yields are low and unreliable. Australia is well placed to become the world's major producer of jojoba oil because of the varieties used, the amenable climate and the technical skills of our farmers.

While good husbandry is a prerequisite in any agricultural enterprise, the timing of many of the operations in jojoba growing is not as critical as for some other crops. This makes it a relatively easy crop to integrate with existing land-use practices as well as offering a reliable return to supplement farm income.

Markets and marketing issues

Sales are limited to the high price, low volume markets that match the current low world production of about 1000 t/year. The cosmetics and skin-care industry buys 90% of present production, using the oil in its natural form or modified to a cream or wax. It is common for a single company to buy a number of modified forms from a processor and incorporate them directly into a range of cosmetic and hair care formulations. The market for pure filtered oil for use as a skin moisturiser is expanding rapidly.



The remaining 10% of production, coming from second pressings of seed and solvent-extracted oil, has use in the sulfonated form as an additive in special lubricants. The current production of jojoba oil is far too small to be of interest to the large oil companies but smaller specialist lubricant companies are keen to use it.

An industry overview presented in 1994 estimated the market potential to be 200,000 t of oil per year with about 10% going to the cosmetics industry and most of the remainder for lubricants. In 1993, the world production was about 1100 t, or about 0.5% of the potential market.

Prices are likely to remain high until the cosmetics market is fulfilled, they will then need to fall for the oil to be accepted as a lubricant. Prices fluctuate in the range $30–70/kg at present because of the unreliable supply.

Production requirements

Much of the inland cereal growing area of Australia is well suited for jojoba production. Varieties have been selected that match the climate of these areas, but other factors such as soil type and rainfall must also be considered.

Jojoba requires soils that have good internal drainage and are not subject to flooding. Apart from pH, the chemical properties are less critical, as fertilisers can be used. Soils with a pH of less than 5.0 are generally not suitable for jojoba because of aluminium toxicity problems. Jojoba is planted as hedge rows on low banks to facilitate weed control and harvest. It can be planted on land with slopes of up to 3% provided the banks are contoured.

Aspect is generally not important on land with an altitude of less than 350 m, but for higher areas aspect needs to be considered to reduce the risk of late and severe frosts that can cause damage at flowering.

Jojoba should not be grown in areas receiving less than 350 mm rainfall annually unless supplemental irrigation is available. Where rainfall exceeds 600 mm per annum the threat of fungal attack on leaves during wet winters increases dramatically.

Jojoba seed pods

About the author

Peter Milthorpe is Senior Research Agronomist, NSW Agriculture, at the Agricultural Research and Advisory Station, Condobolin, NSW (see *Key contacts* for address). Over the past 17 years he has carried out extensive research into many aspects of jojoba. Varietal selection and pollination requirements have been main areas of research, followed by the development of sound management strategies. In 1993 he began growing jojoba on the family farm.

Most cereal-growing areas are suitable for jojoba production.

Jojoba seed pods form along the plant branches.

Varieties

To ensure ease of management and one-off harvests it is important that all plants in any crop are the highest-yielding varieties. They must behave in a uniform manner, particularly in flowering, seed-set and ripening. This can be achieved only by using cuttings from registered varieties. Seed should not be used.

Three female varieties of jojoba have been selected as suitable for most Australian conditions. These varieties—Barindji, Wadi Wadi, and Waradgery—have been selected for their consistent high yields and registered under the *Plant Breeders Rights (PBR) Act*. They are now freely available for commercial production. Two male varieties—Dadi Dadi and Guyambul—which are prolific producers of compatible pollen, are well suited for pollinating the female varieties selected.

Agronomy

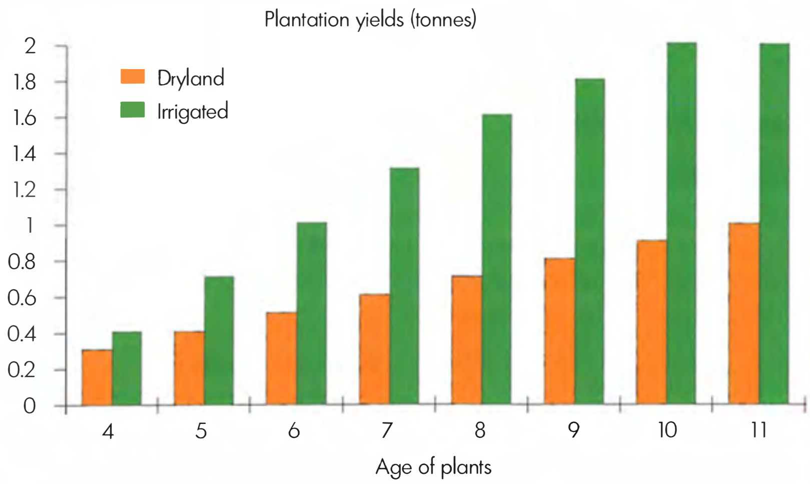
Field layout should be planned to ensure that the rows run on the contour on sloping land. This will minimise erosion, provide access and locate drainage areas, and ensure that the most efficient use of the land is made. Hence it is advisable to survey the site well in advance of any work. Jojoba are grown in hedgerows on low banks spaced 5 m apart. The plants are spaced 1.6–2.0 m apart along the rows. Headlands of 5–7 m are needed at each end of the rows to permit machinery access.

Jojoba grows slowly in the first few years and has little competitive ability against fast-growing annual weeds. Good initial land preparation to reduce weed seed numbers assists in later management as it is much easier to work on a broadacre basis than try to control weeds around individual plants. Small areas of jojoba can be established and maintained by using three point linkage machinery that is normally found on farms, but large plantations will require special equipment. Land should be fallowed at least 12–18 months before planting to build up soil moisture reserves and reduce weed seed populations. Banks should be constructed at least 3 months before planting to allow them to settle. It is advisable to limit the length of plant rows to no more than 500 m as crop management becomes difficult, particularly at harvest, in long row layouts. The initial fertiliser application should be banded along the rip lines at about the time of bank construction. Ideally it should be placed 15–20 cm below the plant line where it will be readily available to the jojoba but unavailable to weeds.

There are two main planting seasons each year. The first is in spring as soon as the soil temperature rises above 20°C at a depth of 10 cm. This gives the young plants maximum growing time before the onset of winter. The second is during autumn, from late February until early March, after the worst of the hot weather is finished. However, plants can be planted successfully during the heat of summer provided extra care is taken with watering during early establishment.

Planting can be done by hand or with machinery, depending on numbers. About 5% of plants need to be male and planted throughout the plantation to ensure adequate pollination of the female flowers. The newly planted cuttings must be watered in as soon as possible after planting. Follow-up waterings are most important if planting is done during hot weather to allow the roots to grow out of the potting mix into the surrounding moist soil.

Weed control is the next most important operation after planting, followed by plant shaping in the second year to produce well-shaped plants that can easily be harvested.



Estimates of yield for dryland and irrigated jojoba

Avoid areas receiving less than 350 mm annual rainfall unless supplementary irrigation is available.

Pests and disease control

Few pests and diseases affect jojoba. Following planting, birds and rodents may be troublesome. Galahs and sulphur-crested cockatoos occasionally attack young plants, nipping them off near ground level, but rarely killing them. There have been a few instances where white cockatoos have caused about 5% deaths in small plantings, but these problems were solved by using scare guns. Rabbits and hares can do similar damage, especially when there is a shortage of green feed.

Aphid attack during spring has been recorded from several young plantings but has never been serious. Insecticides can readily control any outbreak, but experience has shown that natural predators do a better job. Spiders and birds have colonised some plantations and between them control most insect pests. Following fruit set, Heliothis caterpillars can attack the developing fruit. The caterpillars appear to invade over a short period, soon after flowering, before the capsule becomes too hard for the grubs to penetrate.

Table 1. Projected per hectare returns for jojoba.

Yield (kg/ha)	Seed sales ($/t)		Oil sales ($/L)	
	$3500	$1500	$35	$15
1000	3500	1500	15 750	6 750
1500	5250	2250	23 625	10 125
2000	7000	3000	31 500	13 500

Only isolated outbreaks have been recorded and, to date, none of the attacks has been serious.

Some plant deaths have been attributed to a soil-borne pathogen attacking the roots. These outbreaks have occurred after periods of extreme wet and attempts are being made to isolate the pathogen responsible.

Frost can affect the reproductive function of the plant as well as the vegetative parts. The recommended varieties have been selected to minimise yield damage. Vegetative damage can occur on new growth of all varieties and at all ages, especially in dry winters when frosts are more severe. Frost damage is usually restricted to new growth made just before winter, which has not had a chance to harden off. While it looks bad no lasting damage is done. The flower buds survive and the frosts have the effect of tip pruning, encouraging new lateral growth in the following spring.

Key statistics

Managed jojoba plantations in Australia have increased from about 25 ha of 'seeded' material in 1992, to almost 200 ha in 1996. All recent plantings have used the recently released varieties. Oil production has been below 3 t/year, but will increase from 1997 when the new material reaches maturity.

Harvesting and processing

Off-the-ground harvesters are used overseas and machines of similar design will be used here. The final design of harvesters for Australian conditions has yet to be completed as broadacre plantings are only just reaching maturity. After harvesting, the seed can be readily cleaned of leaf and other debris and stored until required for crushing. Crushing is carried out using a standard oilseed press. Once crushed the oil is filtered and may be pasteurised and bleached before storing in sealed drums until required, or sold.

Economics of production

A well-managed plantation set out with properly selected varieties using 1250 plants ha/ will yield about 1 t of seed per hectare after 10–11 years under rainfed conditions, and up to 2 t if irrigated. The main cost is the purchase and rearing of the seedlings (up to $3750/ha) with land preparation and planting costing another $1000/ha. Further costs will be incurred if irrigation is used, the cost varying according to circumstances. Following establishment, there will be management costs for weed control and plant shaping until the crop starts production in year 4 or 5. Harvest costs are about $1/kg for hand-picked seed from small plantations but should drop to $0.20–0.30/kg in larger, machine-harvested plantations. Projected returns from lower and higher yielding crops and for different seed and oil prices are given in Table 1.

The present price of seed in Australia is around $4500/t, with the oil extracted entering the high-priced cosmetics market.

Key contacts

NSW Agriculture has been responsible for most of the recent research leading to the development of suitable varieties and offers advice. Other State departments of agriculture or their equivalents also have advisory officers.

Key messages

Select

- suitable climate
- well drained soils
- suitable varieties
- good management strategies

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Miscellaneous Crops

Coffee

James Drinnan
David Peasley

Introduction

Interest in re-establishing Australia's coffee industry rekindled in the mid 1980s with the advent of machine harvesting, followed by the development of management systems to produce a high quality coffee, and the attraction of a domestic market now worth $483 million in retail value.

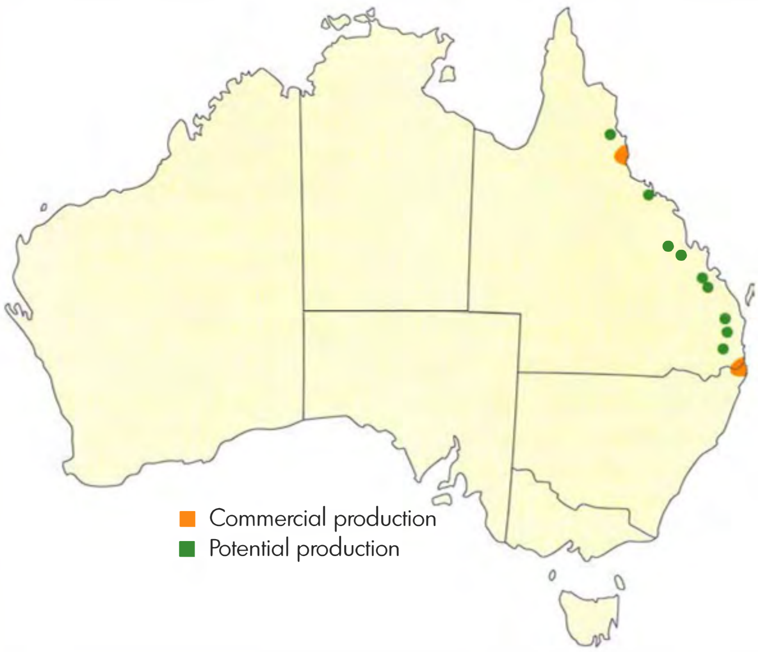
Australia's high labour costs early this century were largely responsible for the decline of the local coffee industry. We could not compete with countries such as Brazil, Mexico, Indonesia and Central America who dominate the world coffee trade, which is now worth a massive $A24 billion annually.

With machine-harvesting, an Australian coffee industry could reduce its harvesting costs to one tenth of the cost of hand-harvesting and so be more cost-competitive with imported coffees. There is however a limit to the protected, frost-free land available for the production of high-quality, high-yielding, machine-harvested coffee. The sub-tropical growing areas of eastern Australia favour the production of high quality 'Arabica' coffee which is preferred for the expanding 'Roast and Ground' market.

Many of the traditional production, harvesting and processing techniques have had to be modified or replaced to suit mechanisation and the different economic and climatic conditions in Australia.

Freshness, a lower caffeine content and a 'pesticide free' or 'organically grown' image are attractive qualities of Australian Arabica coffee. There is also interest overseas in the mild, medium-acidity, 'stomach-friendly', speciality coffees which are being produced. The challenge is to produce enough consistent quality coffee to take advantage of these market opportunities. Growers will have to cooperate in eliminating the individualism and poor practices which have led to industry fragmentation and inconsistent quality.

Coffee is free of major pests and diseases, and can be grown near urban areas. Moreover, the coffee growing areas of Australia are well supported by the high-quality engineering, fabrication and servicing expertise needed for machine harvesting and processing.



Markets and marketing issues

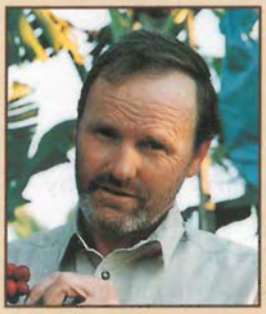
Coffee has become increasingly popular in Australia and more Australians are now brewing their own coffee with higher quality 'Arabica' coffee. Consumption of coffee in Australia has increased by 60% over the past 10 years, with the higher quality 'Roast and Ground' market now comprising 20% of total imports. Demand for 'Roast and Ground' coffee increased by 6.3% in 1996 compared to 1.4% for instant coffee.

Only 200 t of green bean (the final dried stage before roasting) were produced in Australia in 1996, compared with the 49,000 t of green bean we imported. Imports were worth around $225 million in 1996.

Our small domestic production of Arabica coffee is sold to the higher-priced speciality outlets and tourist market in Australia, while some is blended with imported coffee. Half of Australia's total production (100 t) was exported in 1996. Not enough is produced for reliable supply to major buyers or to develop exports.

Coffee can be sold as 'cherry' straight from the tree to a processor within 24 hours of harvest, but most is processed on farm or cooperatively to the dry parchment stage. Parchment coffee can be stored for up to 12 months until ready for sale or processed further by 'hulling' to produce green bean, ready for roasting. Roasting is a specialised, skilled operation which needs experienced operators.

About the authors



James Drinnan (BAgrSc, PhD), Senior Horticulturist, Queensland Department of Primary Industries, Walkamin Research Station.

In his eight years of coffee research James studied the physiological aspects of coffee production, including flowering behaviour, water relations and growth patterns. In 1992 he completed a PhD on coffee flowering at the University of Queensland.

See *Key contacts* for the authors' addresses.

David Peasley (WDA), (CPAg), Horticultural Consultant

David has worked for 10 years to develop a coffee industry in northern New South Wales, evaluating cultivars and investigating harvesting systems suitable for the terrain and climate of the area. In 1990 he organised a coffee marketing summit to ensure that there would be a market in Australia for commercial coffee.

In developing markets for Australian coffee, consistency of supply and quality are critical. Coffee growers are starting to appreciate the advantages of shared processing and the development of a quality-assurance scheme.

World coffee prices are subject to dramatic fluctuations, usually because of climatic effects in Brazil where a quarter of the worlds' coffee is produced. The prices have varied from around $2.50 to $12/kg green bean over the past 20 years with an average price of around $4/kg. Recently world coffee prices declined from the end of 1994 at $7.50/kg, to the end of 1996 at$3/kg. Prices rose sharply due to a shortage of supply particularly in the Arabicas, peaking to over $8/kg in May 1997. Prices received for Australian coffee have varied with the world price but have generally been much higher. North Queensland which produces 90% of Australia's coffee has received from $3–8/kg while the smaller quantities of NSW-grown coffee have attracted much higher prices partly because of its scarcity and partly because of the promotion efforts of local producers.

Production requirements

Coffee originated as an understorey plant in the highland tropical rainforests of Ethiopia. These areas are frost-free, have mean daily temperatures of 20ºC and an average annual rainfall of 1800–2000 mm well distributed but with a dry season of 3–4 months. The important factors in site selection in Australia for coffee production based on machine harvesting are as follows.

The cultivars grown today in Australia prefer a relatively mild, frost-free, subtropical climate with mean temperatures between 15°C and 25°C and as a consequence coffee does well in elevated tropical and frost-free sub-tropical areas (see Figure 1). Temperatures below 7°C and above 33°C slow growth and reduce production. Coffee is highly susceptible to frost and even short periods below 0°C will defoliate the bush.

The rainfall pattern is probably one of the most critical requirements. For machine harvesting to be successful a reasonable synchronisation of flower and fruit ripening is required. In an area with a reliable dry season during flowering (winter/spring) and where there is irrigation, flowering can be controlled by deliberately water-stressing the trees and then heavily irrigating. A reliable dry season and cool temperatures during fruit ripening (winter) are also required to aid machine harvesting. (See figure 1). Wet and warm conditions during fruit ripening can dramatically reduce harvested yields. For the rest of the year reasonably well-distributed, high rainfall is preferred. Good irrigation can overcome the need for high rainfall.

Key statistics

Australian production

- Qld – 180 t
- NSW – 20 t
- Exports – 100 t
- Imports – 48,868 t

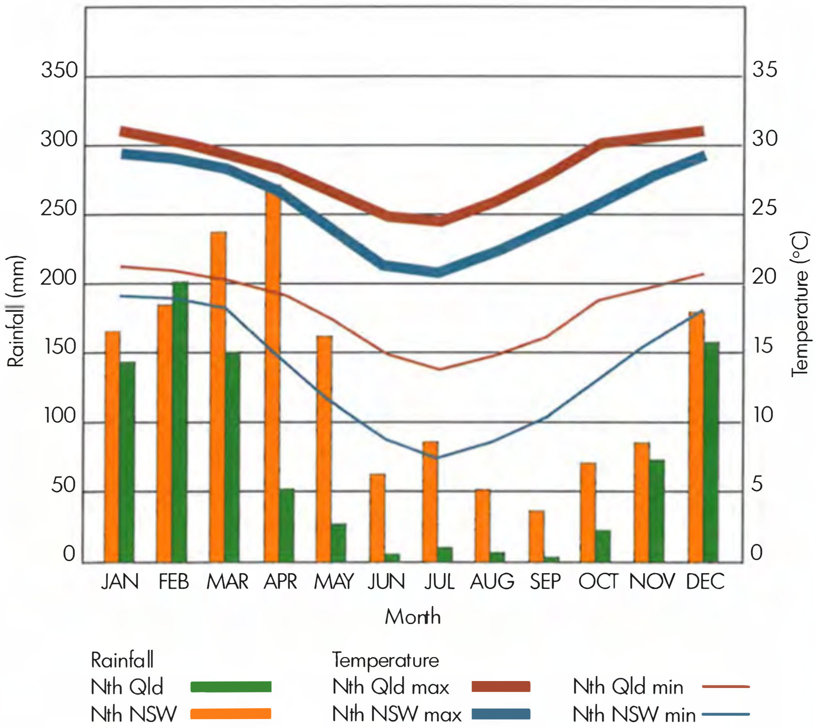


Figure 1. Rainfall and temperature patterns for the Tweed Valley in northern New South Wales and Mareeba in north Queensland.

The soil needs to be well drained and aerated, as coffee does not tolerate waterlogging. A free draining depth of at least 0.5 to 1.0 m is preferred. Where coffee is grown on more fertile, volcanic soils, irrigation and fertiliser management is much easier than on very sandy soils.

Overseas literature recommends an altitude of 900 to 1200 m for Arabica coffee cultivation. However, this altitude really relates to suitable temperature and rainfall patterns. Research in Australia and growers' experience have shown that good quality coffees can be grown at altitudes from 15 to 900 m.

Flat ground is preferred for machine harvesting, but hydraulic levelling on the machine allows it to harvest up and down slopes of up to 15° and side slopes 6–8°.

Shade is not required for coffee production. Where adequate nutrition and irrigation are provided, yields are greater without shade.

The K7 variety is preferred for cooler subtropical areas where it yields heavily and is suited to machine harvesting.

Coffee trees are very sensitive to wind damage, which can severely reduce productivity: therefore windbreaks are essential. Wind can cause ringbarking in young trees and also cause them to lean over, which reduces the efficiency of the harvester.

Given these climatic requirements many areas along the Queensland and Northern New South Wales coast are suitable for coffee production.

Varieties

Initial plantings were based on the local cultivar Kairi Typica and Bourbon, Arusha, Caturra and Blue Mountain imported from PNG. Yields were disappointing with only 0.5 to 1 tonne/ha green bean. Some newer cultivars have now been evaluated by QDPI and NSW Agriculture. The recommended cultivars for northern Queensland include Catuai Rojo, K7, SL6, Mundo Novo, Catuai Amarillo and Kieperson. For the cooler subtropical areas of northern NSW and southern Queensland, K7 and SL14 are preferred for warmer sites, and a local selection CRB is suitable for cooler locations.

Agronomy

Being highly self-pollinated, coffee is propagated by seed and therefore does not need grafting. Seedlings are available from specialists nurseries particularly for mechanical planting. However, most growers raise their own seedlings. Seed is also available from existing growers, the DPI or NSW Agriculture.

Key messages

- Machine harvesting essential
- Attractive domestic and export markets
- Limited suitable land available
- No major pests or diseases

Seedlings are raised in seed-germination beds under 50% shade and then transplanted into polythene planting bags at the 2–3 leaf stage. Seed takes 4–8 weeks to germinate. The plants are then gradually sun-hardened and are ready for field-planting in about 8–12 months. Some growers have planted seedlings bare-rooted. Planting is usually carried out at the start of the wet season.

Trees are planted in hedge-rows for ease of machine harvesting, weed control, fertilising, irrigating, spraying and mowing.

Trees are spaced between 0.75m and 1.0 m apart within the rows and 3.0 to 4.0 m apart between the rows (depending on the cultivar and climate). This gives plant densities of 2500–4400 plants/ha. A ground cover is usually established between the rows to reduce erosion.

Before planting, the ground is usually deep ripped and cultivated along planting lines. Trees are planted into mounds (30–40 cm). It is important that rocks, sticks and stumps are cleared from the field to enable the harvester to operate smoothly.

Windbreaks should be established before field-planting as trees are sensitive to wind damage. *Pinus caribaea* and Barner grass (*Pennisetum* spp.) have been used successfully as windbreaks.

Coffee trees are fairly slow to establish in the field for the first 12–18 months because of inherently slow growth rates and poorly developed root systems. Therefore weed control in the early establishment period is critical. The planting rows should be mulched and kept weed-free for 50 cm either side of the plants. Pre-emergent and post-emergent herbicides are used but young trees are sensitive to spray drift.

Fertiliser

Coffee trees grown intensively under full sun have a very high nutrient requirement. Before planting, fertilisers are incorporated into the planting strip (especially phosphorus) and soil pH is adjusted to 5.5 to 6.0. Fertiliser is then banded along the rows at 4–6 week intervals. As trees come into full production (year 4 and 5) 300–400 kg nitrogen and potassium/ha and 15 kg phosphorus/ha are needed. Foliar fertilisers are often applied in times of peak need. Common nutrient deficiencies experienced in Australia have been zinc, iron, copper and magnesium.

Irrigation

Coffee requires a plentiful supply of water all year round except during the late stages of floral development (September–November) when a period of water stress can be used to manipulate flowering. Under-tree and overhead irrigation have been used. Under-tree is preferred.

Pest and disease control

Australia is fortunate to be free of the two most serious and widespread coffee diseases: coffee berry disease and coffee rust. Coffee trees in Australia have only a few pest and disease problems and these are not serious. Green coffee scale (*Coccus viridis*) and mealy bug (*Planococcus* spp.) are the two most common pests. Both attach themselves to leaves and young branches and draw nutrients from the tree. In large numbers they cause a general decline in tree health, affecting yield. Ants are often associated with scale and mealy bug infestations. In warm, dry environments, scale and mealy bug can become widespread and may need to be controlled chemically. Research trials have shown that where there are only minor infestations, natural predators (parasitic wasps) and the disease (*Verticillium*) usually keep populations under control.

The only significant disease in coffee trees is cercospora *(Cercospora coffeicola)*, a fungus which causes leaf spotting and defoliation and attacks fruit, causing premature ripening. It is most prevalent in warm, wet weather, in nurseries and early field-establishment. In bad attacks, repeat sprays of foliar copper (copper oxychloride 4 g/L) will control the fungus. However, attention to plant nutrition and good soil-moisture conditions will assist the plants' resistance to infection.

Harvesting and processing

The harvester is a large self-propelled three or four-wheel machine which straddles the rows of coffee.

Within the harvester frame are two vertical shafts which carry hundreds of fibreglass fingers (40–50 cm in length). The fingers vibrate laterally and rotate through the bushes as the harvester moves forward down the row. The cherry (fruit) is dislodged from the branches by the action of the fingers and is caught on a catching frame which transports the cherries to storage bins on the harvester. An Australian coffee-harvester is now commercially available (manufactured by AUSTOFT). Other machines for use on smaller plantings and steeper land are under evaluation, including a tractor-drawn

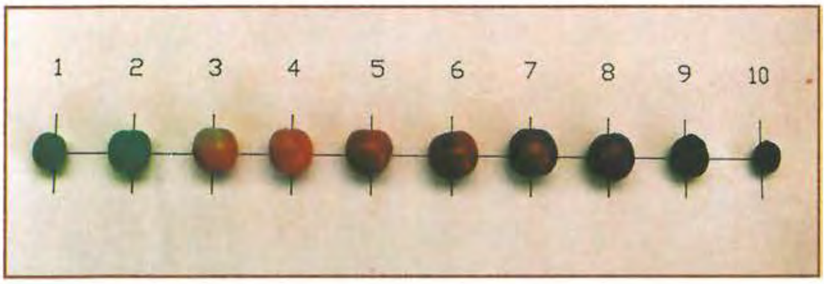
Austoft coffee harvester, showing the straddle shaker mechanism machine with a similar harvesting mechanism and hand-held harvesters which remove cherry from individual branches.

As ripening commences, the coffee cherry changes from green to red, then to dark red-purple and eventually black when over-mature.

There are two processing methods to obtain green bean which is used for roasting. The simplest method is 'dry processing' where coffee is harvested over-ripe and then dried to 10–12% moisture. The dried skin and parchment is then removed by hulling, leaving green bean coffee. This method is commonly used to process robusta coffee and produces a lower quality product than 'wet processing'. In wet processing, coffee is harvested as ripe, red cherry. The cherry is pulped to remove the two seeds from the skin. The seeds are fermented to remove the sticky mucilage layer around them and then dried to 11% moisture. The parchment and silver skin are then removed by hulling and polishing, leaving green bean coffee. The bean is referred to as 'green bean' because of its colour. It normally takes between 6 and 7kg of cherry to produce 1kg of green bean coffee. This method of processing produces the best quality coffee. Most of the coffee produced in Australia is processed using the 'wet' method. The problem with this has been that to produce top quality coffee all the cherry must be red ripe and immature green cherries must be removed.

When machine-harvesting is used (as opposed to hand-harvesting), cherry samples for processing often include various amounts of over and under-mature fruit as well as mature, ripe, red cherry. These samples when processed with traditional processing equipment, produced very poor quality coffee. Until recently this was the major problem of the newly established Australian coffee industry. New processing systems have now been developed. One developed by QDPI uses size grading and selective tyre-pulping to separate cherry of different maturities, so that top quality coffee can be produced even from samples with mixed cherry maturities. Another system now being imported from Colombia requires much less water than traditional systems, is portable and removes the sticky mucilage without lengthy fermentation.

Coffee growers usually process their coffee to parchment stage or green bean and then sell this to processors for blending and roasting. However, some of the Australian growers roast their own coffee and do some of their own marketing. Quality is assessed by bean size, freedom from defects and liquor quality. Prices are significantly better if you sell the bean as speciality or gourmet coffee. No central marketing group body or cooperative yet exists but cooperative and group marketing initiatives are under way in northern NSW.



The ten stages of coffee cherry ripening from immature (green) to over-mature (black)

Economics of production

An economic assessment of coffee production in north Queensland was undertaken. These economic studies estimated farm profitability for machine-harvested coffee, establishment costs, rates of return and break-even yields and prices.

The studies investigated the profitability of a new 20 ha plantation and a 10 ha plantation on an existing farm, with both farms using contract harvesting. Both studies found that these plantations were marginal for the yields and market prices at that time. The conclusion from those reports was that a yield of 2 t green bean/ha and a price of $4/kg are required to make coffee production profitable. These yields and prices would appear achievable given the improved world prices and increase in yields from improved production practices, varieties, harvesting and processing techniques since these reports were written.

Establishment costs are estimated at \$5,600–\$7,000/ha (year 1), with operating costs of \$1,700–\$2,000/ha (year 2 and 3) and \$2,700–\$3,000/ha (year 4–10).

Zentveld's—pioneering a high tech gourmet coffee industry

Dogged persistence and a keen eye for innovation and business has seen NSW North Coast coffee grower John Zentveld bridge the gap between a dream and commercial reality.

Backing his judgment less than 10 years ago, and encouraged by David Peasley from NSW Agriculture who used RIRDC funding to investigate the potential for a coffee industry, John committed himself totally to converting his ailing avocado plantation at Newrybar near Byron Bay to a commercial coffee growing and processing enterprise producing high-quality gourmet coffee. By combining world leading technology in harvesting and processing with a flare for innovation he has developed his dream into a thriving, vertically integrated commercial business.

Starting with a selection of promising varieties from a RIRDC-funded variety evaluation project in the early 1990s, John has cooperated with researchers in NSW and Queensland developing management, harvesting and processing techniques which he has further developed and modified to suit machine harvesting and local conditions.

Mechanisation has been the key to John's success, removing the high labour cost which has restricted the development of the coffee industry in Australia for the last 70 years. Some examples of his innovations are a nursery system developed for producing uniform cell-grown seedlings for mechanical planting and a processing system compatible with machine harvesting.

Two years ago John formed a consortium of growers committed to maximising the potential of the area to produce gourmet quality coffee. John's group purchased the first mechanical harvester for NSW.

Backed by his daughter-in-law Rebecca, who is principal of the coffee marketing company, Zentveld's of Byron Bay and who has a natural flair for marketing and roasting coffee, he has taken the whole process from pioneer planter to gourmet producer of high-quality roasted coffee.

A new 20 ha plantation requires a capital outlay of around $560,000 before any income is received. A 10 ha plantation required $135,000 until the first harvest, and an additional outlay of $20–50,000 for a processing factory.

It has been suggested that a return of price of $6/kg green bean is needed before coffee growing becomes competitive with macadamia growing in northern NSW.

First commercial yields are expected in the third year after transplanting. Full commercial yields are expected five years after transplanting, where conditions are good. Some form of tree rejuvenation (pruning) will be required in years 7 to 10, depending on the variety, to maintain the trees in a productive and manageable state for harvesting. There is a reduction in yield in the year following pruning. Stumping (pruning to 30 cm above ground level) may be required after year 10, depending on climatic conditions, production history and management. No production occurs for two years after stumping which should be done on a rotational block basis to maintain cash flow.

The following table gives a summary of expected net income (after growing, harvesting and processing costs are accounted for) per year for one hectare of coffee harvested by machine. Recovery % refers to the percentage of prime cherry recovered by the machine after harvesting losses.

It is assumed that it will cost $1.00/kg of green bean to process. This amount has been accounted for in the above examples.

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Expected net income per hectare per year

Yield	Recovery (%)	$2/kg	$4/kg	$6/kg	$8/kg
1500 kg/ha	70	1050	3150	5250	7350
	80	1200	3600	6000	8400
	90	1350	4050	6750	9450
2000 kg/ha	70	1400	4200	7000	9800
	80	1600	4800	8000	11200
	90	1800	5400	9000	12600
2500 kg/ha	70	1750	5250	8750	12500
	80	2000	6000	10000	14000
	90	2250	6750	11250	15750

Japanese green tea

Ange Monks

Introduction

Green tea belongs to the group of flowering plants termed Camellias, mostly used as garden ornamentals. *Camellia sinensis* is one of two subspecies used in tea production world-wide. The three varieties Sayamakaori, Yabukita and Okuhikari are currently being tested in Australia.

Green tea has been propagated from plants originally brought through quarantine from Japan. The experience in Australia has been similar to that of New Zealand in that high mortalities resulted from the fumigation treatment with methyl bromide to prevent the entry of Kanzawa mite and other pests into Australia. The surviving plants have been successfully propagated to increase the supply of plants for various trial plantations around the nation.

Green tea planted in Tasmania is now entering its fifth year. The crop is a perennial and is not regarded as mature until it has been established in the field for five years. There have been difficulties, which include a lack of suitable soil types, climate and frost damage. Trials have been established in the north-east and a further site is to be planted in the south of the state. During the pruning, which sets up the plucking table for the first flush and harvest, minor wind and frost damage is removed. The plants then flush and this new growth is removed for processing into green tea.

Markets and marketing issues

Demand for green tea is increasing world-wide because of interest in its medicinal value. There has been a large market throughout Asia for the different forms of green tea and it plays an important role in traditional diets. The range of green-tea types and qualities available in the Asian area varies from a form known as gunpowder to the very high quality ceremonial teas only used on special occasions.

Japan's own import of green tea is growing while its exports are decreasing. The trend in Japan is to value-add to green tea. Green tea can be used as an ingredient in ready-to-drink teas, soft drinks, ice cream, biscuits and lollies. The human health issues are also gaining popularity: green tea has been linked to cancer prevention and to anti-ageing effects.

There is very little information available on the newly-emerging green-tea industry in Australia as there are no traditionally processed green-tea sites at a commercial stage. Information on other markets around the world can be patchy. Japanese production peaked in the early 1980s with 61,000 ha and this has undergone a slow reduction since then of around 8%. 1993 saw a production of 420,200 tonnes of raw leaf produced – over 30,000 tonnes less than in the early 1980s. The highest yield/ha of green leaf is 9.2 (1993). The highest yield of made green tea was 2,251 kg/ha, and the lowest yield was 664 kg/ha. Prices paid for fresh leaf at the farm gate vary from farmer to farmer, through the season and between years. There are generally three harvests per season with the first harvest in Japan being the best. Average prices range from $26.00 to $33.00 per kg of green leaf. The prices can vary as many as nine times from the first harvest to the last harvest.

Production requirements

Green tea in Australia is in the later stages of testing. A large amount is known about its agronomic requirements. The new flushes of green tea are harvested. Only the soft lush growth is taken and this generally consists of the topmost bud and the next two or three leaves. The first flush, usually in November in Australia (slightly earlier in more northerly areas), is generally thought to be the highest quality and is also susceptible to late frosts. Site selection is very important in planning a green-tea planting. Good drainage of soil water and cold air is very important to prevent water-logging and the pooling of cold air around the plants. Wind damage can drastically lower the quality of tea that is produced. The best aspect would be a northerly facing, gently sloping site with good drainage and protection from wind.

Green tea develops a strong deep root system with some surface-feeding roots. As the bushes mature they spread out and crowd out most weeds. Before the canopy matures, they can suffer weed competition, root damage from excessive tilling between the rows and from lack of moisture. Moisture is also essential to move fertilisers through the soil so that the plants can use it.

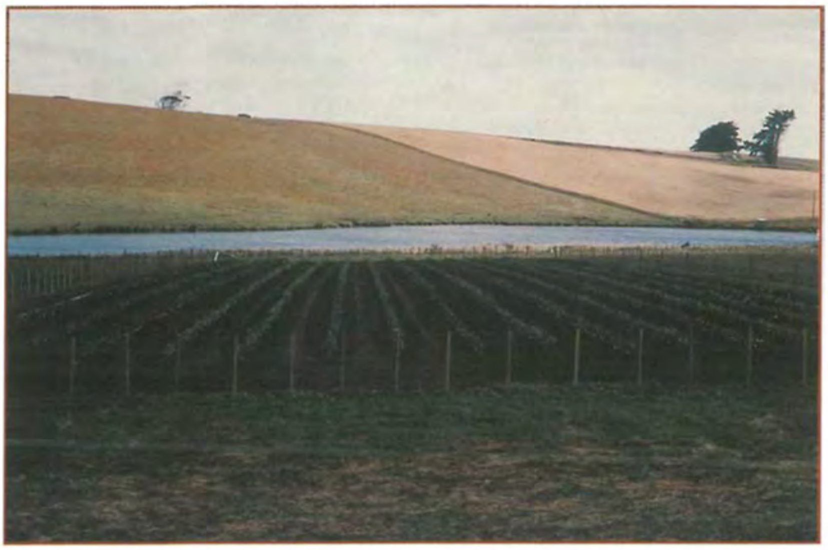
Varieties

Of the three varieties at present in Australia (Sayamakaori, Yabukita and Okuhikari) 80% of Japanese plantings are of the variety Yabukita, which tends to be higher quality after processing although Sayamakaori yields are higher in colder climates.

About the author

Ange Monks (BScHons) is a horticulturist with the DPIF. She is currently enrolled in a Grad. Dip. Ag. Sci. (Hons). Ange is project leader for green tea which has been sponsored by RIRDC, HRDC, Roberts Pty Ltd and a group of private entrepreneurial farmers. See *Key contacts* for address.

Green tea production in Japan



Tasmania's first green tea plantation was established at Devonport in 1993.

Green tea is produced from clonal material by cuttings. The DPIF is continuing to acquire germplasm for other varieties that may prove suitable for the production of green tea in Australia and for the range of climate types available for agriculture.

Pest and disease control

Green tea came from Japan where there is an extreme pest problem. Before they were established in field trials, plants were quarantined for a period of 18 months. This extended quarantine period was necessary to disinfest plants of Kanzawa mite (*Tetranychus kanzawa*), an exotic species of mite found on the plants during the quarantine period. The plants were then disinfested by fumigation with methyl bromide.

There are currently no pesticides in use on the green tea in the DPIF plantings.

Key statistics

- Japan's production is 420,200 of fresh leaf
- 61,000 ha under crop in Japan but declining
- Average consumption of green tea per person in Japan 1,040 g
- Average price for green tea in Japan is A$6.73/ 100 g

Key messages

- Huge range of product type
- Opportunities for value adding
- High cost for traditional processing machinery
- A perennial crop with a 5 year wait to first harvest

Harvesting, post-harvest treatments and processing

Green tea can harvested by hand or by mechanised harvesters which are either hand-held or mounted on modified tractors. Hand picking produces the highest grades of final product although the labour costs are very high. Two-man harvesters are efficient in small areas and are reasonably priced, fully imported to Australia, at around $3,000. A mounted tea-harvester is made in Australia (North Queensland) and can be made with various widths of cutter bars, with the machine itself mounted on tracks.

Processing equipment has been designed and made in Japan for traditionally made teas and reflects the traditional hand processing. The processing is quite involved, with various stages of drying and rolling. The difference between green and black tea is essentially one of processing. The fresh leaves are steamed to denature the enzymes which would normally be active after picking and would turn the tea into black tea.

The first stage in processing is the steaming machine. Steaming denatures polyphenoxidase enzymes to prevent subsequent oxidative fermentation of the leaf flavenols. It is these flavenols which produce the polyphenols giving the colour, aroma and the mouth-feel typical of black tea. The steaming prevents fermentation almost instantaneously and it is this process that retains the bright green colouration typical of Japanese green teas. This process, which lasts for only 45 to 60 seconds, reduces the water content of the leaves to 75%. The leaves are then transferred to the primary drying tea-roller which twists and dries them at temperatures of around 90–110°C for 40–50 minutes. The process further reduces the water content to 50%.

Leaves are transferred to the secondary drying tea-roller which presses and twists the leaves, breaking up their cells and producing an even distribution of water content. This roller is heated to 60°C and has rolling hands which dry and roll the leaves to produce the characteristic shape and aroma of green tea. The tea is then transferred to a tea drier which reduces the water content to between 13 and 6%.

A batch plant that can process 2kg of fresh leaf costs up to (installed) $120,000. According to figures from Japan, to process 40 ha of tea plantation costs between $3 and 5 million.

Economics of production

The green tea crop is perennial and is not regarded as mature until it is five years old. Capital costs include fencing, plant and equipment, irrigation, mulching, planting by hand, windbreaks and plants at 18,000 per hectare costing $14,400. The initial cost of the processing equipment is the highest as previously stated.

After modelling the production, and basing the figures on optimistic yield figure prices, the top table shows figures for dry weight production.

The effects of a 10% and 20% increase and decrease of first and second cut tea yield are shown in the lower table. A 10% reduction in yield results in the enterprise becoming an unattractive investment.

	Green tea yield Year 4 kg DW/ha	Green tea yield Years 5+ kg DW/ha	Green tea price $/kg DW
First cut	0	1400	$25.00
Second cut	600	1000	$12.50
Third cut	200	200	$5.00

Tea yield	Investment return (IRR) %	Net cash flow when fully developed $/yr
+20%	20	$117,887
+10%	17	$102,367
Standard	14	$86,847
−10%	11	$71,327
−20%	8	$55,807

Mechanical harvesting of green tea in Japan

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The olive industry

Susan Sweeney
Gerry Davies

Introduction

Olives, for both oil and table fruit, are an international commodity. The development of a local industry must therefore be considered in an international context. Australia has the climate, physical resources, horticultural infrastructure and expertise to support a modern olive industry. However, other southern hemisphere countries also have the resources and have started developing an olive industry. In addition, the resources are in demand by other horticultural industries within Australia.

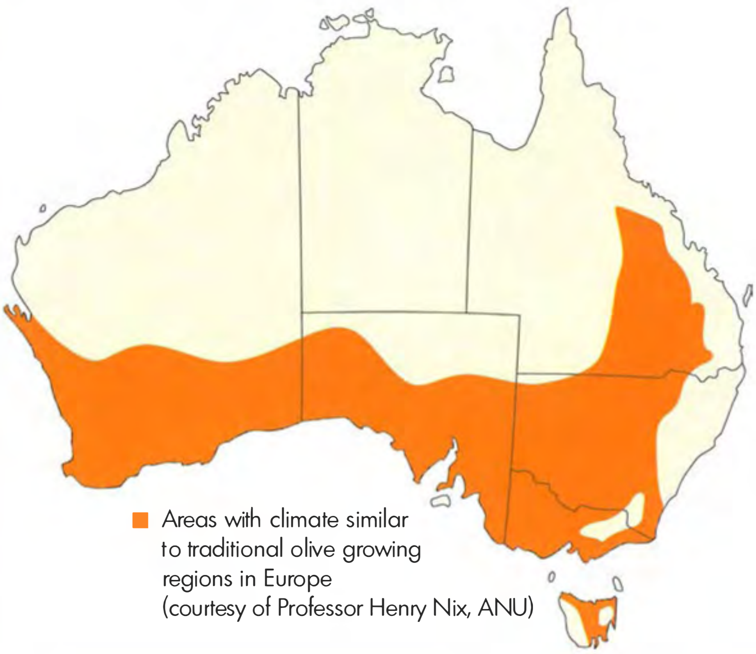
Despite this, olives, particularly for oil production, have the potential to become a substantial horticultural industry based on existing domestic demand and the development of export markets in Asia. The health benefits of olive oil and the interest in Mediterranean cuisine, ensure that it is a popular choice for consumers across the world. Nevertheless, locally produced olive oil must be able to compete against other vegetables oils with similar chemical characteristics and alternatives, including imported olive oils, which are cheaper.

Markets and marketing issues

Olive markets are dominated by Spain, Italy, Greece and Tunisia which account for approximately 80% of table fruit production, 85% of oil production and a similar percentage of consumption of olive products.

World production of olives has risen by about 1% per annum and consumption of olive oil has risen roughly 1.5% per annum over the past twenty five years. The perceived health benefits, a continuing interest in Mediterranean cuisine and promotion by the controlling body of the industry, the International Olive Oil Council, are all stimulating market demand for olives and olive oil.

Australia currently imports approximately 16,000 tonnes per year of olive oil and 7,000 tonnes per year of olive fruit, valued at roughly $90 million and $20 million, respectively. The average annual growth rate of olive oil imports has been 15% for the past eight years. There are no accurate figures for local production but it is estimated at about 2,500 tonnes, most of which is used for pickling. It is generally accepted that about 95% of olive oil consumption is met by imports.



■ Areas with climate similar to traditional olive growing regions in Europe
(courtesy of Professor Henry Nix, ANU)

About the authors

Susan Sweeney has an honours degree in Agricultural Science and has been working with Primary Industries South Australia for eight years. Her previous positions were as a research officer evaluating woodlots irrigated with saline water and also as a Property Management Planning Officer for horticulturalists.

Gerry Davies is Principal Industry Consultant (Fruit, Vegetable and Ornamentals). He has worked for Primary Industries South Australia for twelve years on a wide variety of land and water management projects. Over the past two years he has been involved with olive industry development issues at a State and national level.

See *Key contacts* for the authors' addresses

Strong local demand and the potential for exports into increasingly affluent Asian markets has seen a renaissance in the Australian olive industry (Japan has experienced a 500% increase in per capita consumption of olive oil since 1983). It has been estimated that output from recent plantings could provide 30%–40% of demand for olive oil on the domestic market within 5 to 10 years. It is important therefore for the local industry to quickly develop both domestic and export markets for Australian olive oil.

The growth in interest in olive oil production is undoubtedly driven to some extent by the high prices ($22 to $65/litre) which are currently being achieved by some locally produced oils. In contrast, lower quality imported oils, predominantly from Spain, are retailing at $8 to $12/litre in supermarkets. This implies that the import price is around $4/litre or less. Between these extremes lies the most likely price point for a good quality, Australian extra virgin oil.

A reasonable price, acceptable taste and reliable supply of sufficient volumes of consistent quality oil are all required to gain acceptance and shelf space in supermarkets. This is important in underpinning the growth of the industry.

Economies of scale and modern production techniques based on world's best varieties and practices can place Australia in a strong competitive position. This will be assisted by a reduction in European subsidies over the next five years due to the GATT agreement. Even so, it must be recognised that there is competition from other southern hemisphere producers, notably Argentina and Chile, and competition from other vegetable oils such as canola.

Production requirements

The olive originated in the Mediterranean region and will grow well in areas of Australia with a similar climate, i.e. cool, wet winters and warm dry summers. They will produce in other areas as long as they have the correct chilling requirement (winter temperatures fluctuating between 1.5°C and 18°C) and summers long and warm enough to ripen the fruit. The trees can suffer severe damage at temperatures less than –5°C. Hot dry winds or rain at pollination in late spring may reduce fruit set.

The shaded areas on the map show regions in Australia with similar climatic regimes to traditional olive growing areas in Europe. There *will* be areas not indicated on this map where olives will produce successfully.

Olives will grow in most soil types as long as they are well drained. Steep slopes should be avoided if it is intended to use machinery, especially mechanical harvesters, which may not operate efficiently at slopes greater than 15–20°.

Traditional batch processing of olives for oil

Key messages

- Maximise productivity by variety selection and management
- Minimise costs through mechanisation and economies of scale
- Understand and develop markets
- Nurture industry growth through coordinated organisation

Olives can be grown without irrigation but water stress will significantly reduce yields. Californian research has shown they need approximately 1000 mm of irrigation plus rainfall annually to produce maximum yields. Good yields are possible using less water but this requires careful irrigation management to ensure minimal water stress during critical growth stages.

Varieties

There are over 100 known varieties of olives in Australia. The most common are the oil varieties Corregiola, Frantoio, Paragon, Picual and Nevadillo Blanco; the table varieties Kalamata and Hardy's Mammoth; and the dual purpose (considered suitable for oil and table) Mission and Manzanillo.

There are also some new, high-yielding oil varieties, soon to be released from quarantine, that have been specifically bred for intensive cultivation e.g. Barnea and FS17.

Due to the huge demand for planting stock in Australia there may be a wait of up to two years before some varieties become available from nurseries. Planting stock should be purchased from reputable nurseries with good quality control. Any waiting period should be spent developing a business plan and preparing a site.

Agronomy

Although olive trees are hardy, to yield well they require the same high level of management as other commercial tree crops, particularly in their first few years of growth.

Soils should be tested for their nutrient status before planting as many corrections are easier to make without trees in the ground. Olive trees will respond to fertilisers and it is important to take regular soil and/or foliar samples for nutrient analysis. As well as ensuring a correct balance of trace elements, a combination of NPK should be applied, half in autumn and half in spring.

Young trees are vulnerable to strong winds and should be staked or trellised, particularly if a single straight stem is required for mechanical harvesting. Protective paper or foil wrapping around the trunk will protect the young tree from sunburn and herbicides. Competition from weeds can be a major problem for young trees but is easily managed by using herbicide along the tree row leaving a strip of pasture in the middle of the row which is regularly slashed.

The young tree will need to be pruned to encourage it into the correct shape (usually vase or conical). Once this is achieved the tree should be pruned every year to maintain the shape and to maintain tree health by allowing air and light to enter and circulate through the tree canopy. Olive trees are biannual bearers and pruning at the correct time during 'on' years will encourage more shoots and subsequent fruit growth in the following 'off' year.

The time from planting to first harvest is variety dependent and also dependent on management techniques. There are some new varieties bred specifically to have a reduced non-bearing period that will come into commercial bearing at only 2–3 years of age. Most olive varieties though will take at least 4–5 years and even longer if not cared for properly. Young trees can be induced to yield earlier by correct irrigating, fertilising and pruning.

Pest and disease control

A major advantage of olives is that they are relatively pest and disease free in Australia. Very few chemicals should be needed for successful olive cultivation and it has good potential to be grown organically, particularly in drier areas.

The most common pest is brown olive scale or some other forms of scale. Two insect pests becoming a problem in the eastern states are the Olive Lace Bug (not to be confused with beneficial lace wings) and the Green Vegetable Bug. The Curculio beetle or weevil is a common pest in new plantings in former pastures.

All of these pests can be controlled but they should be positively identified and expert advice sought to minimise indiscriminate spraying of broad–spectrum insecticides which will also kill beneficial insects.

The main fungal problem is peacock spot which results in leaf fall and poor fruit set. It is more common in humid areas and correct pruning to allow adequate air-flow through the leaves will help keep it under control. Copper sprays can also be used.

Olives are also harmed by some soil-borne pathogens e.g. phytophthora and nematodes common to other fruit trees. If the site has been previously used as an orchard the soil should be tested for these organisms and fumigated if necessary.

Key statistics

World table olive production and consumption 1996

Olive production and consumption		
	Running average (4 yr)	1996–97
Production ('000 t)	956.8	1,141
Consumption ('000 t)	997.9	1,054
Olive oil production and consumption		
	Running average (4 yr)	1996–97
Production ('000 t)	1,899.4	1,572.0
Consumption ('000 t)	1,881.3	1,757.5
Australian imports 1996		
	Olive oil	Table olives
Value ($'000)	87,369	21,874
Volume ('000 t)	15,865	7,000

Source: ABS

Share of edible oil segment in supermarkets 1996			
	Volume share (%)	Value share (%)	Value ($m)
Olive oil	19.4	42.5	78.5

Source: Foodweek Industry Yearbook 1997

Harvest, handling and processing

Olives have traditionally been harvested by hand but for an economically viable large-scale operation mechanical harvesters are essential. Mechanical harvesters currently available can either shake individual limbs or vibrate the whole trunk. Olives are generally harder to shake off than other tree fruits and abscission treatment with ethylene may be required.

Fruit should be processed as soon as possible after picking because of risks of oxidation and fermentation. This applies to both table and oil olives. Table olives will need to be graded and put straight into treatment tanks. There are many pickling recipes and processing methods but a common system is to immerse the fruit in caustic solution for a few days to remove bitterness then wash and ferment it in brine for anywhere between 3 and 12 months.

Oil is extracted from olives by crushing them and then separating out the oil from the paste using a traditional batch press or a modern continuous process system that will handle larger volumes of fruit more rapidly. A continuous process system with a capacity of 1.5 tonnes of fruit per hour, will cost around $500,000.

Olive oil has a quality grading system based on chemical and taste tests. Virgin olive oils (extra virgin, virgin and ordinary virgin) are obtained solely from the fruit

How the McCulloch's life was consumed by the olive tree

Mac and Buzz McCulloch retired after a successful life in farming some 10 years ago and began to slow down and do all those lovely things that retired people do. They have long been interested in the flora of Australia, so their attention was drawn by an attractive tree which looked like it might be a native but which they were unable to identify. A botanist friend enlightened them: the tree was not a native and, indeed, was one of the oldest species of cultivated tree-the olive tree.

They were so impressed with the general health and appearance of the tree, that they bought two olive trees for a newly established orchard. When the olive trees grew much better than the other fruit trees in the poor granite soil of the orchard, the germ of an idea to grow a few more and start a small cottage industry was established.

Getting up-to-date information about olives proved quite a challenge for the McCullochs. After many unproductive phone calls, a daughter who was working in NSW Agriculture came up with an address for 'Olives Australia'. This was a family company just starting an olive nursery at Grantham in Queensland, and it was a great help to the McCullochs.

The McCullochs planted 250 trees and visited South Australia and Victoria to study the olive industry. It is small and fragmented industry, but the people involved were extremely helpful.

With support from the Inverell Business Centre, the McCullochs called a public meeting. They had a simple objective-to get 10 people who would each grow 250 olive trees, and become the basis of a small, 'boutique' operation. They set up a small room with 15 chairs for the meeting-55 people turned up!

The McCullochs now have an organisation with 70 members and about 70,000 trees in the greater Inverell and Moree area. A modern factory using the latest processing technology is to be established in the area. Mac McCulloch and another local grower, Les Parsons, are on the board of the Australian Olive Association. In retrospect the establishment of an olive enterprise now sounds so easy to Mac McCulloch, but it wasn't! Information was hard to find and was expensive. The McCulloch's cash book entries for 1996 show that they spent some $8000 for travelling, stationery, literature, telecommunications, and many other items in furthering their olive enterprise.

Much of the information they received was conflicting and confusing, and from different countries with practices going back centuries. They still do not know what are the best varieties to grow, what yields to expect in different areas, what harvesting methods to use, and whether or not it will all be profitable. They can make only an educated guess about these things, because trees planted today are many years away from profitable production.

Nevertheless, in 1997 they had the pleasure of pressing their first 90 litres of oil, which was of very high quality.

by mechanical or physical means without using chemical extractants or excess heat (greater than 28°C) that will alter the characteristics of the oil. Refined olive oil is obtained from virgin olive oil by refining methods used to improve the odour, flavour and taste. Olive oil (sometimes labelled pure olive oil) is a blend of refined and virgin olive oil. The olive pomace (solid material left after the first oil extraction) can be treated with solvents to extract the remaining oil to produce olive pomace oils suitable for human consumption.

Olive oil should be stored in airtight and light-proof containers at a constant temperature below 15°C to reduce the risk of oxidation which causes the oil to go rancid.

Economics of production

Establishment costs will vary considerably for each grove. To simplify matters the price of land, irrigation headworks and special soil preparations are not considered. The major establishment costs are therefore the trees and irrigation system. Trees cost between \$5–\$10 each depending on age and source. Irrigation reticulation varies from \$1000 to \$4000/ha depending on system design and labour costing. With a further \$1000/ha for ripping and soil amendments, establishment costs lie in the order of \$3000 to \$7500/ha (assuming a standard planting density of 250 trees/ha).

Annual gross return is determined by tonnage, oil percentage and price. Assuming a planting density of 250 trees/ha; 50 kilograms of fruit/tree with 20% oil (specific gravity 0.9):

2) $250 \times 50 = 12,500$ kg of fruit (3,500 small jars of olive)

3) $12,500 \times 0.2 = 2,500$ kg of oil

$2,500/0.91 = 2,750$ L of oil (approx.) (140 drums (20 L) of oil)

Using a price of \$1.30/kg for table fruit in equation 2) above would give a gross return of \$16,250/ha. Production costs (pesticide, pruning, fertiliser, irrigation, herbicide and picking) are between \$6000 and \$8500/ha depending on whether the fruit is hand picked or mechanically harvested. This gives a gross margin of between \$7750 and \$10,250/ha/yr.

Washing fruit on a modern continuous process system

The latest 'central leader' style of planting and trellising

For oil production, assuming the costs are similar and substituting the 'world parity' price for oil of $4/L into 3) above, the gross return is $11,000 giving a gross margin of between $2500 and $5000/hectare.

Thus olive growing for oil or table fruit is in the same league as other horticultural tree crops such as citrus and stonefruit but somewhat less profitable than wine grapes. The important issues are to use the best varieties and management practices such as irrigation to ensure high fruit and oil yields and design the grove to accommodate mechanical harvesting to reduce costs. Throughout the production and processing system attention to quality is essential.

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Nuts

Cashews

The late Elias Chacko
Pat O'Farrell
Sam Blaikie

Introduction

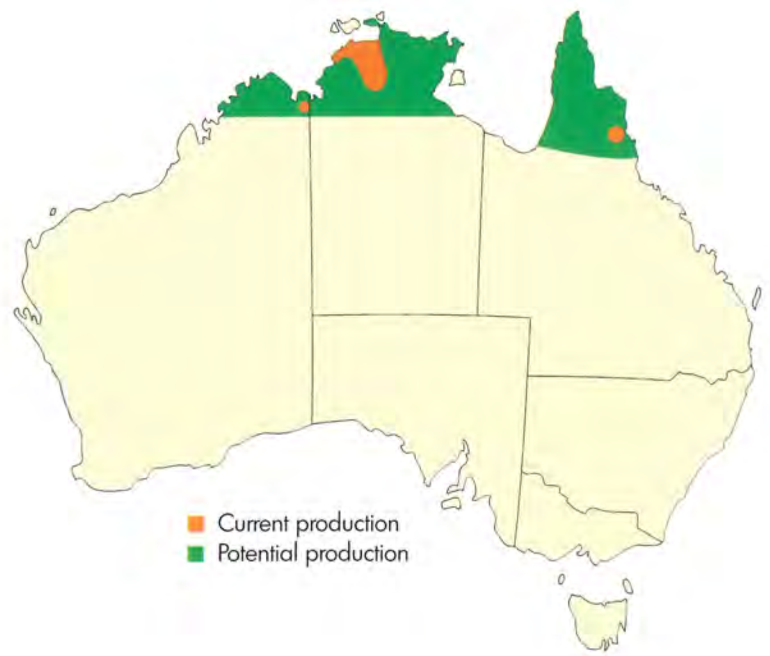
Cashew (*Anacardium occidentale* L.; Anacardiaceae) is a tropical evergreen tree from north-east Brazil. It ranks third in world production of edible tree nuts with a current world production of about 700,000 t nut-in-shell (NIS). This is produced mainly in India, Brazil, Vietnam, Africa and South East Asia. Local consumption and demand by importing countries for cashews continues to increase, providing opportunities for expansion of the crop worldwide.

Cashew is a crop with good potential for the Australian tropics. Large areas of suitable land with adequate water supply are available in the Northern Territory and far north Queensland. It is well suited to the seasonally wet/dry tropical climate and does not suffer the perishability problems associated with other soft-fleshed tropical fruits. It can be stored for long periods and can withstand long-distance transport. Australia currently imports A$26–30m (wholesale value) of cashew kernel annually; a local industry would provide import replacement and create export opportunities for sale of NIS, raw kernel and value-added products.

The Australian cashew industry is currently at an embryonic stage, with one major plantation in north Queensland and two plantations in the Northern Territory. To expand, the Australian industry needs high-yielding (>4 t/ha NIS) selections and management practices to achieve and sustain such high yields. Plantings of at least 500 ha in single or cooperative plantations may be required to (i) establish a brand name in the local/international market, and (ii) minimise the unit costs associated with production and the overseas processing of Australian cashews.

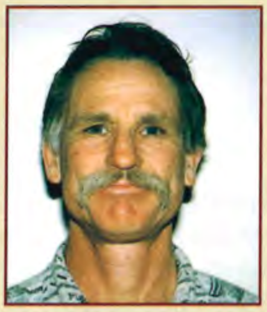
Markets and marketing issues

Worldwide 160,000 t of cashew kernel are traded annually with a retail value exceeding US$2 billion. Of the total world supply, 110,000 t are traded in the international market. India (60%) and Brazil (31%) are the major exporters. The major importing countries are the USA (55%), The Netherlands (10%), Germany (7%), Japan (5%) and the U.K. (5%). Australia imports about 5000 t/ year.



About the authors

The late Elias K. Chacko was a Senior Principal Research Scientist with CSIRO Horticulture in Darwin. Dr Chacko had a distinguished research career in tropical fruit and nut crops in India and Australia. He made a very significant contribution towards the development of an Australian cashew industry through his pioneering research on cashew physiology and the development of high quality cashew varieties. He will be missed by all associated with this new industry.



Pat O'Farrell is a District Experimentalist with the QDPI in Mareeba (see *Key contacts* for address). Mr O'Farrell has worked in horticulture research for over 25 years, mainly in bananas. He has worked in cashew plant improvement and nutrition since 1991.

Dr Sam Blaikie is a post-doctoral fellow with CSIRO Horticulture in Darwin. Dr Blaikie has 12 years experience in irrigated pasture agronomy and has been working on cashew irrigation management since 1995.

As the major importer of cashew, the USA has a strong influence on the world price which is fixed in US$ per pound (1 pound = 0.45 kg) of kernel. The price of W320 grade (320 kernels/pound) over the last 15 years has ranged between US$2.73 and US$3.18. The current price is in the range US$2.4–2.8 and is expected to remain steady, with increased supply (5% per year) being balanced by increased consumption in current and developing markets in Asia, and particularly in India.

Overseas, the nuts are collected from the growers by local traders who in turn sell to large processing companies. After processing, the kernels for export are sold by trading companies to overseas markets through agents or dealers. The major retailers in Australia are supplied by several Australian dealers with kernels imported from India, Vietnam and Brazil. The major Australian dealers are Jorgenson Waring Foods, Michael Waring Trading and Salzo Food Industries.

The current Australian cashew production is about 25 t kernel/ year. The raw nut is shelled overseas and the kernel returned to Australia where it is sold as raw kernel or processed and sold as value-added products. As the Australian industry expands, it is likely that growers will benefit from pooling their production, value-adding and marketing with an Australian brand name.

Production requirements

Cashew is well suited to a seasonally wet/dry tropical climate. The area selected for cashew production should be frost free. Mean daily temperatures of less than 25°C will limit the growth and productivity of cashew trees. Areas south of 16°S are considered marginal for cashew in Australia (see map). Soils should be free draining, as cashew does not tolerate waterlogging.

Cashew is known for its drought tolerance, and in other countries it is generally grown under rainfed conditions on soils of low fertility. Yields under these conditions are typically 0.5–1.0 t nut-in-shell/ha. In Australia, much higher yields are required to offset high establishment and labour costs. To achieve these yields (target > 4 t/ha NIS) requires superior genetic material and inputs of irrigation, fertiliser and pest control.

Flowering and fruiting of cashew in Australia extends from May to December, which corresponds to the dry season. Irrigation should be applied during this time at weekly intervals and the harvest should be completed before the wet season commences in January. Fertiliser requirements will vary with soil type, and regular applications of major and minor elements may be required. Deficiencies of nitrogen, sulfur, phosphorus, zinc and molybdenum have been observed in Australian plantings.

Varieties/breeds

Because of the industry's infancy, availability of proven genetic material is limited. At the moment Australian plantings are mainly hybrids/selections imported from overseas and this material is not well suited to local climatic conditions.

A joint government research and grower breeding program is currently developing high-yielding hybrids adapted to Australian conditions. Some selections have been made (1988 bred hybrids) and are being evaluated at a range of sites in Queensland and N.T. Full evaluations of the best selections to date will take at least another five years. Inquiries regarding availability of the selected material should be directed to CSIRO. Limited genetic material of some local selections is available from QDPI and the N.T. Department of Primary Industry and Fisheries.

The cashew fruit consists of an 'apple' with a nut attached

Key statistics

Quantity and value of cashew kernel imported into Australia and estimated Australian production of kernel in 1996

Kernel imports (t)	5000
Import value (A$m)	26–30
Australian production (t)	25

Agronomy

Before development of the property starts, a farm plan defining the placement of infrastructure (buildings, roads, dams, underground irrigation mains, etc.) and a schedule of development tasks should be formulated. Careful site preparation (land clearing, windbreaks, erosion and drainage structures, soil tilth and amelioration, irrigation installation, root and rock removal) will lead to better tree growth and easier future harvesting. In areas where giant termite (*Mastotermes darwiniensis*) exists, root removal is also important to reduce the risk of infestation.

With good cultural management, grafted trees will produce sufficient yield by the third year after planting to warrant mechanical harvesting. Nuts with 'apples' attached are harvested from the ground, then cleaned, dried, apples removed and stored. A well-managed plantation will require propagation/nursery facilities, an under-tree sprinkler irrigation system with fertigation capability, tractors, slasher/weedicide boom, mist-blower, hedger, sweeper/harvester, nut cleaning, drying and apple removal equipment, and storage facilities.

Cultural practices are designed to promote healthy trees while at the same time managing canopy growth, nut yield and quality, and timing of nut drop. In the period from planting to first harvest, a canopy framework is developed which is structurally sound, shaped to facilitate spray coverage and mechanical harvesting, and maximises nut yield in the shortest time from planting.

The critical aspects of management are insect control during vegetative growth, flowering and early nut development, irrigation during floral and nut development, and adequate nutrient application before vegetative and floral development. Additional operations include pruning immediately after harvest (before vegetative growth season), preharvest trash removal, and weed control.

Cashews require all the major nutrients (N, P, K, Ca, Mg and S). They are particularly sensitive to zinc deficiency, and iron deficiency has been observed in trees growing in high pH soil (>8.0). Nitrogen management is important because it has a major influence on vegetative growth which determines nut yield and timing of nut drop. In tropical areas, irrigation systems should be designed to apply 500 L/tree/week and water supply should be capable of delivering this rate for 5 months of the year.

Pest and disease control

Various insect and animal pests are prevalent in the cashew-growing areas in Australia. No diseases are of commercial concern although anthracnose *(Colletotrichum gloeosporioides)* has been a problem in areas where rainfall occurs throughout the year.

Some insects are seasonally confined to the wet season, e.g. mango shoot caterpillar *(Penicillaria jocosatrix)*, leaf miner *(Acrocercops spp.)* and leaf roller *(Anigraea ochrobasis)*. Others can attack trees at any time during the year, e.g. giant termite *(Mastotermes darwiniensis)*, tea mosquito bug *(Helopeltis australiae)*, fruit spotting bug *(Amblypelta lutescens lutescens)*, red-banded thrips *(Selenothrips rubrocinctus)* and pink wax scale *(Ceroplastes rubens)*.

Key messages

- world trade exceeds US$2 billion
- expanding world demand
- imports valued at A$26–30m
- tropical Australia well-suited to cashew
- genetic and agronomic research under way

With the exception of giant termite, insect pests attack tender tissue (leaves, shoots, flowers, developing nuts and apples) reducing leaf area and causing defoliation and shoot death. Control during vegetative growth, panicle emergence and early nut development is most

Cashew tree with developing nut crop

important, as damage during these periods can result in the greatest reduction of nut yield. Control is best achieved by regular monitoring, biological control (e.g. green ants, which research in the NT has found feed on a range of cashew insect pests) and strategic sprays during critical times.

Giant termite, a problem in the Northern Territory and Western Australia, burrows within the tree, gaining entry through the roots from subterranean canals. Infestations can exist unnoticed until death of the tree. Control requires constant surveillance and baiting.

Fruit bats and rats can also cause economic loss. Fruit bats feed on the apple and can remove significant quantities of nut from the plantation boundaries. Windbreak plantings have proven effective in encouraging bats to feed on the cashew apples within the plantation and leave the nuts, which they do not eat, within the plantation. Rats can destroy polyethylene irrigation pipes and fittings. Damage can be minimised by baiting and plantation hygiene (grass control).

Harvesting, handling and processing

Cashew fruit (nut with apple attached) fall to the ground when mature. The fruit is swept together with trash material (leaves, branches, grass) to the centre of the inter-row and then raked up by a harvester. Tree canopy, weed growth, ground surface condition and surface trash influence the rate of harvest, the quantity of nuts which can be harvested and volume of extraneous matter mixed with harvested nuts. Preharvest ground preparation is necessary to remove low branches, level the ground surface and remove trash. While the harvester aspirates light extraneous material, further cleaning may be required before the nuts are dried and the apples removed. Nut moisture must be reduced to <9% before storage.

Large bunch of developing cashew nuts

There are no shelling facilities in Australia. The process of kernel extraction is complicated and laborious and involves removal of the shell's caustic oil, shell cracking and testa removal. Australian nuts are currently sent to China for kernel extraction.

Nuts may be sold as NIS, raw kernel or as processed value-added products (roasted, chocolate coated, etc). NIS price is influenced by nut size and kernel recovery which determines the yield of kernel to the processor. Kernel price is influenced by quality standards, e.g. kernel size and percentage of breakage, and these are defined by the International Organization for Standardization (ISO).

Australian nuts are sold mainly as processed value-added products. Such sales reap higher returns compared with NIS and raw kernel sale. In addition, broken kernel, which would otherwise be downgraded under ISO standards and so draw a lower price, can be marketed at the same price as premium grade kernel.

Economics of production and processing

The economics of establishing a 100 ha cashew plantation in the Northern Territory has been calculated. Profitability was determined on the basis of returns from NIS sale and assumed a sale price of A$1.33/kg.

A summary of costs and returns is presented in Table 1.

In this study, the total establishment cost was $943,950 and included, in addition to land purchase, all payments necessary to prepare the land for its intended use, *viz* clearing, cultivation, grafted trees, planting costs, bore, fencing, power, buildings, plant and equipment. In reality it is unlikely that a 100 ha planting would be attempted in the first year of development.

The conclusion from this study was that a yield >4 t/ha NIS and a c.i.f. price >A$ 1.33/kg are needed to achieve an internal rate of return (IRR) >10% in real terms. Sensitivity analysis showed that the IRR is highly sensitive to variations in yields and prices. Identification of varieties capable of producing a sustained yield >4 t/ha and a nut quality which would attract a premium price offer the best chance of improving profitability.

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Table 1. Summary of cashew development budget ($'000/100 ha).

Year	0	1	2	5	10	20
Income	0	0	76.8	308.0	512.8	1,312.0
Capital costs	239.3	704.7	77.7	4.0	4.0	4.0
Variable costs	0	61.0	96.1	158.4	195.1	195.1
Fixed costs	0	92.5	91.5	91.5	91.5	91.5
Nett cash flow	−239.3	−858.2	−188.4	54.1	222.2	1,021.4
Cumulative cash flow	−239.3	−1,097.5	−1,285.9	−1,320.3	-428.7	2,432.8

Cashew pioneer—Peter Shearer

Peter Shearer, a successful clothes retailer and businessman, first took a serious interest in cashew growing when he saw how precocious and high yielding young trees were. He had been considering cashew for some time as a possible crop to complement his existing macadamia enterprise. Cashew offered two important advantages to Peter: different times of harvest for the macadamias and the cashews meant that he could make more efficient use of his macadamia harvesting equipment; and the cashew nut offered exciting marketing prospects for expanding his value-added macadamia plans.

Peter secured a 1140 ha property at Dimbulah 100 km west of Cairns as part of a government program supporting the development of pioneering industries. The climate of the area was similar to that of the Indian State of Kareela, which is a major cashew producer. He planted his first seedling trees on Cashew Australia in 1989. His recent plantings, which have expanded his planted area to 240 ha, have been of high yielding clonal trees.

Peter completed his first machine-harvest in 1994 and since that time yields have increased steadily. There are no shelling facilities in Australia, so the raw nuts are sent to China for kernel extraction, which is currently a very labour-intensive process. The kernel is returned to Australia and processed in a range of confectionery products (chocolate coated; honey and sesame coated). He has established a very lucrative local and interstate market for these products. His most recent marketing success was supply to Kmart who sell Peter's product under their premium house brand name of 'Australian Choice'.

One of the biggest hurdles Peter has had to overcome, has been the construction of a machine to remove the cashew 'apples' from the nuts after harvest. He has now achieved this. He says his biggest future challenge will be completing the project which will require planting the remaining 900 ha.

Peter Shearer has been an active supporter of industry R&D programs and openly shares his experience in developing cashews with others in the industry.

From his experience in pioneering a new crop his advice is: make sure you have sufficient capital and thoroughly investigate all the information you can get on the particular crop.

Cashew industry development champion Peter Shearer (left) discusses a high yielding selection with Keith Hyde.

Chestnuts

Lester Snare

Introduction

The Australian chestnut industry has existed in one form or another for over 130 years. Early records report chestnuts being eaten in the gold rush years in north-eastern Victoria. Fully established chestnut trees are majestic ornamental trees up to 20 m high. They have the potential to yield commercial quantities of nuts, which can be consumed fresh or after processing. Most of the current Australian production is consumed fresh.

Annual Australian production is now 600 t and is expected to increase. At present, the local market is limited to the large European population in major Australian cities, but export to Asia and Japan, in the northern hemisphere off-season, is considered to offer good potential for fresh nuts. In season 1995–96 Australia exported to Japan and Singapore a total of 19 t of chestnuts valued at $111,275.

Up to 500,000 t of chestnuts are produced each year around the world. China, Korea and Italy are the major producers. Other countries to export include Portugal, France and Spain.

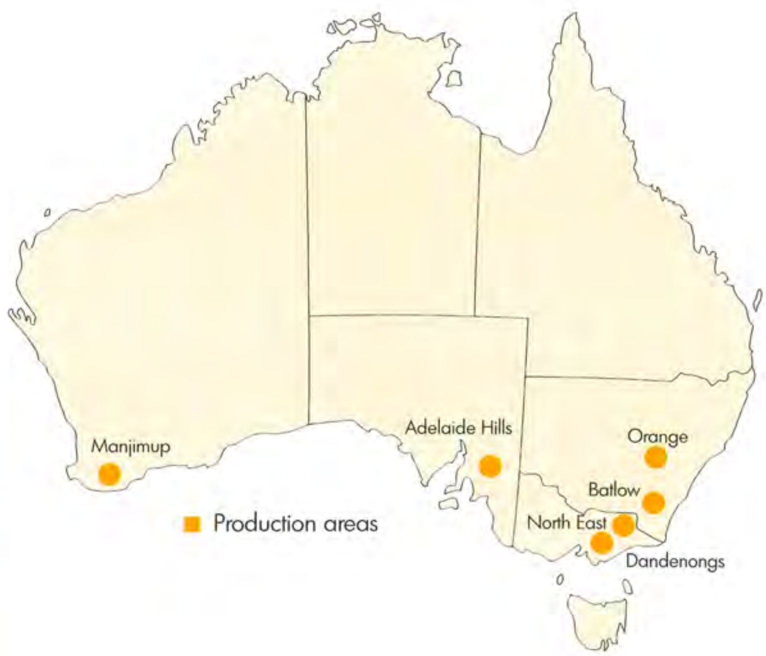
Key strengths of the Australian industry are:

- export potential to the northern hemisphere in the off-season;
- access to a co-ordinated and cohesive approach to marketing and promotion by the industry body;
- the ability to replace inferior varieties with varieties of superior quality and so increase consumer confidence; and
- the opportunity and potential to replace imported processed products.

The Australian industry comprises about 300 producers, although approximately 20 larger growers contribute up to 80% of the total production.

Markets and marketing issues

The majority of product is traded as fresh fruit through the wholesale marketing system. Smaller quantities are sold direct by growers to fruiterers and larger supermarket chains. An even smaller quantity is sold at the farm gate. Sydney and Melbourne markets represent the major wholesale outlets for chestnuts in Australia. The two main markets for chestnuts are the domestic and export markets for the fresh commodity.



Future research is required for the development of the peeled, pre-packaged market and there are currently no large-scale processing or value-adding facilities in Australia.

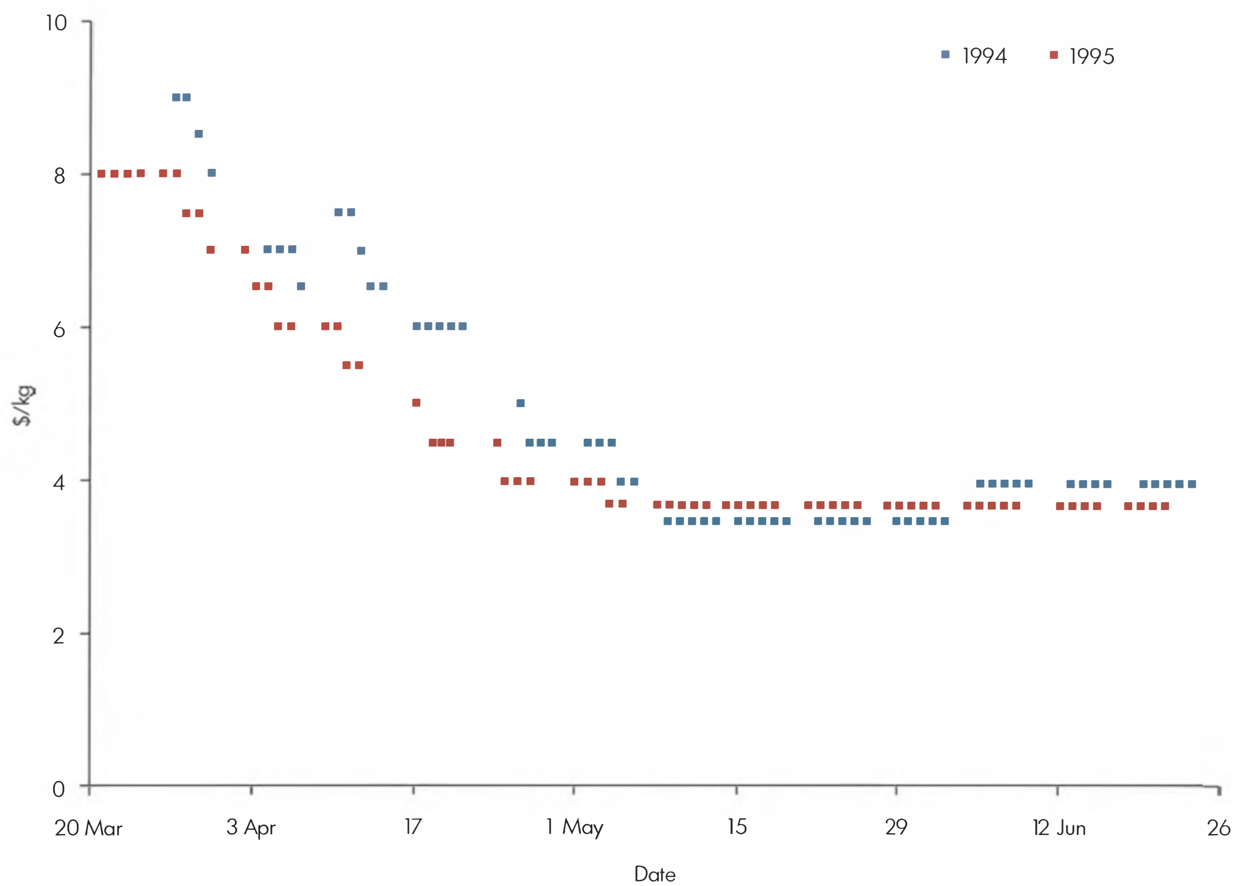
The industry is actively examining the potential for export and processing through the industry body. It is essential for the industry that consumption of fresh chestnuts continues to increase and that substandard product that will discourage new consumers from repurchasing does not enter the market. The very nature of chestnuts, i.e. a seasonal product, considered as an epicurial delight, and requiring a degree of preparation for cooking, creates a challenge for the marketing of this nut.

The outlook for dedicated growers with nuts that have good eating, storing and peeling qualities can be viewed optimistically. In the immediate future there may be an oversupply of inferior nuts from older seedling trees, but with better quality nuts from improved varieties replacing inferior nuts, consumer confidence should increase.

The following graph shows the wholesale prices for chestnuts from the Melbourne Fresh Centre for the 1994 and 1995 seasons. The average wholesale price was between $3.00 and $3.75. The prices for 1996–97 ranged anywhere from $0.30/kg through to approximately $6.00. Higher prices can be achieved for sizes in the 'special' (greater than 38 mm) range.

Production requirements

Chestnuts grow best in high rainfall districts such as the New England and central and southern tablelands. In Victoria, production centers around north-eastern Victoria and the Dandenongs. Other production areas include the Adelaide Hills, South Australia and Manjimup in Western Australia. More than 750 mm annual rainfall is needed for adequate production, although irrigation is required if yields are to be maximised. Once trees are established they can tolerate drought. High summer temperatures can cause nuts to deteriorate, and trees grown in warmer areas have not produced to their full potential. Sites



Chestnut wholesale prices from the Melbourne Fresh Centre for seasons 1994 and 1995.
Source: D. Ridley, Agriculture Victoria.

exposed to the drying effects of wind should be avoided. Suitable windbreak plantings can reduce stress and moisture loss for exposed blocks.

Irrigation frequency will depend on the wetting pattern and the water-holding capacity of the particular soil. Irrigation should not continue too late into the growing season, as it can make nuts crack and over-develop.

Chestnuts require a well-drained, deep soil. The tree is deep-rooting, and the most suitable soils are deep, red basaltic types, with free-draining characteristics. Soil pH should be in the range 5. –6.0. Trees grown in shallow soils are short-lived, as are trees grown in heavy soils with impermeable subsoils. Good drainage is essential for tree health, as chestnuts are susceptible to root rots and other fungal diseases.

Varieties

The industry is based on local selections and imported varieties. Both European and Chinese chestnuts have been imported in recent years. European chestnuts (*Castanea sativa*) are the most widely grown in Australia and form the basis of the Australian industry. Some named varieties include the following.

'Buffalo Queen' is a large, attractive, shiny, dark nut with a prominent stripe and a conical shape. 'Buffalo Queen' peels in hot water and has good flavour when roasted.

'Lucenti' is as attractive, shiny, honey-coloured nut, free falling, of medium size, and slightly sweet. 'Lucenti' is a late maturing variety in Victoria.

'Red Spanish' is a medium to large nut, shiny and relatively sweet.

'Purtons Pride' (also known as 'Emerald Gem') is large, light-tan nut. This nut peels well when roasted and is tolerant to shell splitting.

Some named Chinese chestnuts (*Castanea mollissima*) imported into Australia include: 'Nanking', 'Crane', 'Meiling', 'Skookum' and 'Kuling'. Most Chinese chestnuts have yet to bear commercial quantities in Australia or to be tested in the marketplace.

Trees of the European chestnut *(Castanea sativa)* are purchased as grafted trees, generally on seedling rootstocks, and are available from specialist nut nurseries.

Chestnut processing operation showing small hopper, elevators, sorting table and grader

About the author

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Agronomy

Preparation for planting should begin at least 12 months beforehand and the ground appropriately prepared. If clearing is necessary, then all tree roots should be removed as roots are a source of disease which can later affect the health of chestnut trees. This should be done in winter when soil moisture allows for easier root removal. Deep ripping of the ground down to 0.75 m is advisable if soil conditions and structure permit. Cross ripping can reduce the development of subsurface drainage lines. The aim is to break up the subsoil, improve drainage and allow for better root and water penetration.

Following ripping, soil pH should be adjusted if the soil is acid. Fine agricultural lime is normally spread and incorporated before the trees are in the ground. A suitable legume or cereal crop will increase organic matter and add nitrogen before planting. A soil test for nutritional status can also be conducted at this time.

Chestnut planting distances have become smaller in recent years, aiming for higher yields and better use of available land. New orchards are planted at spacings of between 7 × 7 m and 12 × 12 m, yielding the following numbers of trees per hectare.

7 m × 7 m	204 trees/ha
8 m × 8 m	156 trees/ha
12 m × 12 m	69 trees/ha

Chestnuts are wind pollinated and should be considered to be self sterile for commercial purposes. More than one variety should be planted to ensure cross pollination.

Following planting of young trees, guards can be placed around the tree trunks if rabbits are a problem. The trunks of young trees can be whitewashed with a water-based paint to prevent sunburn if high temperatures are expected.

Key statistics

Imports of chestnuts 1995–96
146 t valued at $577,110

Export of chestnuts 1995–96
19 t valued at $111,275

Most chestnut groves benefit from a balanced nutritional program that supplies mainly nitrogen, phosphorus and potash. Fertiliser application should commence in the second year to avoid fertiliser burn which can occur if the tree has insufficient roots. Further application of fertiliser will be determined by leaf tissue analysis, for which there are standards available.

Chestnuts do not require specialised pruning, but in the first year the tree may require pruning back to compensate for roots lost in the transfer from the nursery. During the first year of growth, train the terminal bud as a leader, and in later years do not allow the trunk to produce branches below 60 cm. Most chestnuts are trained to a central leader, and broken and crossed limbs should be removed early in the tree's life.

Pest and disease control

Chestnuts are attacked by a number of pests. Grasshoppers, eastern and crimson rosellas, white cockatoos, possums, rodents, wallabies and rabbits have caused damage to either the trees or nuts.

Fungal root rots can cause major losses in nut groves, and trees of all ages can be affected. Deaths have been recorded in major growing areas, with healthy trees succumbing rapidly. Other trees may remain alive in a weakened state for a number of years.

Vacuum pickup with elevator, designed to fit into a trailer

Chestnuts within the prickly burr ready to fall

Phytophthora cinnamomii is a common soil-borne fungus that can spread from the base of the tree at an infection point and then move downwards into roots and, later, upwards into the tree. Poorly drained soils aggravate the problem. Fungicides sprayed onto the ground or foliage can limit the spread but not eliminate the organism.

Armillaria root rot *(Armillaria mellea)* is another disease that can affect healthy trees. Like Phytophthora, the symptoms may not be evident until the tree is heavily infected. Armillaria can survive in root tissue from previous introduced trees. Remove old and rotting roots or stumps before planting.

Fungal rots can also affect the nuts during postharvest handling and storage. Preharvest rots have also been observed on falling nuts, with *Phomopsis castanea* being the most likely causative organism. Losses in storage due to *Phomopsis* are often undetectable, as the nut will appear sound from the outside.

Key messages

- Japan is the leading consumer, importing 31,699 t in 1995.
- Chestnuts are classed as temperate nuts.
- Chestnuts are a perishable crop.
- Good drainage is essential for a healthy chestnut grove.

Harvest, handling and processing

The Australian harvest season takes place from late March to May, with supplies available from cool storage in June. Because the nuts contain high carbohydrate levels, mostly in the form of starch, 5% oil and 40% moisture, they are highly susceptible to dehydration and so lose water at normal room temperatures and humidity.

During the harvest period nuts should not remain on the ground for long periods and should be collected at least every two days. Some selections dehisce completely, leaving the prickly burr attached to the tree. Most nuts fall within the burr and can be collected by hand. Purpose-built suction harvesters are available and usually require two people to operate.

After the nuts are removed from the burrs they are graded, usually using a slowly-revolving cylindrical drum that contains holes of different diameters through which the nuts fall and are sorted into different size classes. Chestnuts are currently graded into five industry recognised sizes:

- small (<25 mm)
- medium (29 mm)
- standard (32 mm)
- large (38 mm)
- special (>38 mm)

The nuts should be placed in a cool store at 0°C as soon as possible and then held at this temperature until marketed. Placing nuts in unsealed polythene bags will reduce excessive weight loss in a forced air cooled environment. Unrefrigerated nuts should not be placed in plastic bags. Nuts are marketed usually in 5 or 10 kg cartons, or 25 kg hessian bags.

Economics of production

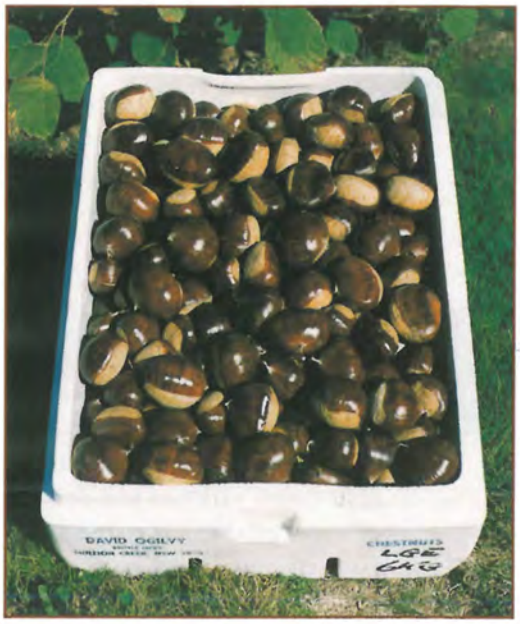
The major costs incurred in establishing a chestnut grove include land acquisition, establishment of irrigation infrastructure, and the purchase of grafted trees.

Typical establishment costs, assuming cleared land, may be:

	$/ha
Soil pH adjustment — lime, 5 t/ha @ $70.00/t	350.00
Land preparation, fertilisers and weed control	300.00
156 trees (planted at 8 m × 8 m) @ $13.00/tree	2028.00
Micro sprinkler irrigation systems (assumes main + sub main to block)	1500.00
Total	4178.00

Suction harvesting equipment costs from approximately $10,000, dehuskers from $3800 and grading machines from $3,000. This equipment is purpose-built and readily available in Australia. A suitable tractor will be required for routine mowing, spraying and general nut grove operations.

Yields have often been difficult to predict because of seasonal variation, possible pollination problems, occasional poor tree health and varietal differences. This makes 'typical' gross margin data unreliable, but representative production figures are given in Table 1.



Freshly harvested chestnuts. Photo: D. Ogilvy.

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Table 1. Estimated production by tree age for grafted chestnut trees.

Tree age (years)	0–4	5	6	7	8	9	10	11	12	13	14	15–19	20–24	25–29	30–40	40+
Estimated annual production (kg)	0	2	5	8	10	12	15	18	22	26	34	40	50	70	100	200

Hazelnuts

Basil Baldwin

Introduction

Although hazelnuts (*Corylus avellana*) were introduced into Australia over 100 years ago, to date they have been grown only on a relatively small scale. Current annual production is estimated to be approximately 15 t of in-shell nuts. However, there appears to be an opportunity for considerable expansion of the local industry, as more than 1500 t of nuts and kernels, valued at more than $7m are imported into Australia every year.

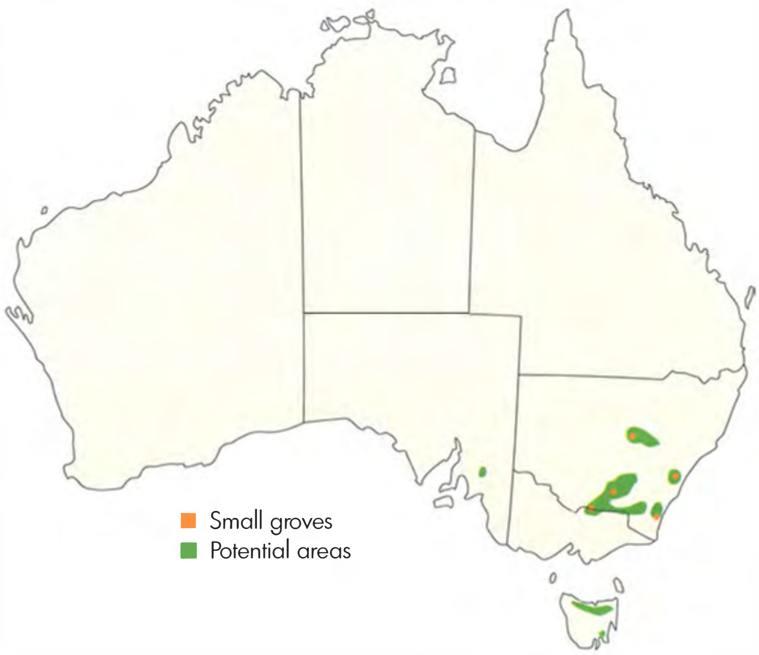
It is considered that the establishment of a local industry could complement overseas production through the provision of fresh, locally grown nuts that could be stored, at a relatively low cost, in-shell, and cracked as required to supply fresh kernels for local processors and consumers. Major users of hazelnuts in Europe are also interested in obtaining nuts from Australia, provided the nuts are of appropriate quality and are available in sufficient quantities.

In addition to the freshness of the Australian product for local users, it has the potential to capitalise on a 'clean and green' image, as few of the major pests and diseases of hazelnuts have been introduced into Australia. In order to capitalise on these market opportunities, there needs to be research to evaluate appropriate varieties and develop efficient production systems. Growers must develop an industry infrastructure of mechanised harvesting, handling, storage, cracking and grading of nuts, orderly marketing and strategic alliances with major buyers.

Markets and marketing issues

Hazelnuts are marketed as two products: nuts in-shell and kernels. Nuts in-shell, marketed mainly for home or table consumption, account for less than 10% of the total market. Most hazelnuts are cracked and sold as kernels, which can be eaten fresh, but the vast majority are either blanched or roasted then used in confectionery products such as cakes, biscuits and chocolates.

The major centre of hazelnut production in the world is in northern Turkey, on the Black Sea coast. There are other important production areas in Italy, Spain and Oregon, USA. The nuts produced by the Turkish and European growers are commonly stored on-farm and then sold during the year to operators of cracking plants. The



cracked kernels are size-graded and placed in plastic vacuum packs which are kept in cool storage to prevent rancidity. The volume and value of imported nuts and kernels in recent years, are given in Table 1. The quantity of imported kernels has generally risen since 1990, as has the average price. Although the unit value is the price paid in the country of origin, importers have a greater cost than this, as they also incur shipping, storage and handling costs.

Many variations are possible in the market chain from production to processing and consumption (Fig. 1).

To date, one of the major constraints to the development of the local industry has been the lack of knowledge on the performance and appropriate management of the introduced varieties that might be grown to achieve the identified opportunities of import substitution.

Table 1. Quantities, values and sources of hazelnut imports into Australia, 1990–91 to 1995–96.

	90–91	91–92	92–93	93–94	94–95	95–96
Hazelnuts in—shell (t)						
Italy	26	14	5	–	–	14
Turkey	7	–	–	25	16	47
USA	52	84	119	96	75	51
Total	85	98	124	121	91	112
Total value ($A'000)	217	157	197	279	269	347
Unit value ($A/kg)	2.55	1.60	1.59	2.31	2.96	3.10
Shelled hazelnuts—kernels (t)						
Italy	107	92	71	114	299	49
Turkey	894	973	1041	794	1061	1372
USA	254	317	331	438	420	408
Total	1255	1382	1443	1346	1780	1829
Total value ($A'000)	4900	5423	5398	7097	9097	8283
Unit value ($A/kg)	3.90	3.92	3.74	5.27	5.11	4.53

Source: Australian Bureau of Statistics

Production requirements

Hazelnut production is favoured by a climate with a cool winter and mild summer, such as is found in the coastal and upland areas of southern Australia.

Hazelnut trees have a poor tolerance to heat, wind and moisture stress. The tree is deciduous and, when dormant, can tolerate temperatures as low as –15°C. However, at the time of pollination, the pollen and stigmas will tolerate temperatures no lower than –5°C. This is not generally considered to be a problem in Australia.

The main northern hemisphere production areas have a Mediterranean-type climate and are in the latitude range 37° to 47°. The climate of locations in Australia, where small hazelnut groves have been successfully established, compares favourably with major northern hemisphere production areas (Table 2).

The growth of hazelnut trees is favoured by well drained, fertile soils with a pH range of 5.5–7.5. Good supplies of irrigation water in the summer months are considered to be essential, especially during the

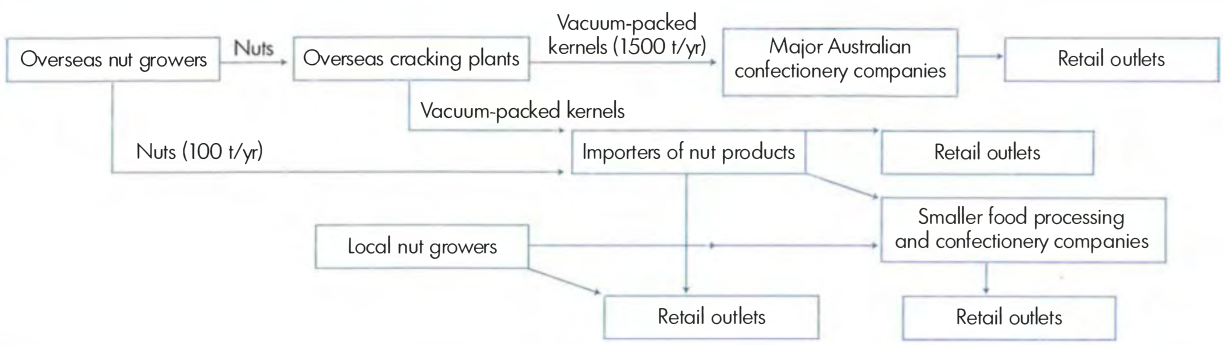


Figure 1. Principal components of the market chain from overseas nut production to processing organisations and retail outlets.

establishment phase of the grove and during dry seasons. Although the major production areas overseas generally have a high incidence of winter rainfall with relatively dry summers, irrigation does not appear to be a common practice in those centres. However, as evaporation rates in Australia are usually higher and rainfall is more erratic, irrigation facilities are generally recommended. Dry weather during the harvest period is advantageous.

Hazelnut trees do not tolerate strong winds and therefore the selection of sheltered sites or the planting of wind breaks before establishing the grove is very important.

Flat or gently sloping sites are preferred to facilitate operations within the grove, particularly mechanical harvesting.

Varieties

Selecting the most appropriate hazelnut varieties for planting is a very important decision. There are two main aspects that have to be considered: the productivity of the tree and the marketability of the nuts. Ideally, the varieties planted should be both productive and of a type for which there is a market demand.

Although a wide range of varieties can be sold in-shell, there is a customer preference for nuts that are large with a clean, shiny appearance and even size. Varieties that meet these requirements include 'Wanliss Pride' from Australia and 'Ennis' from the USA (Table 3). 'Wanliss Pride' is a sweet-tasting nut when harvested and stored under appropriate conditions. It is, however, prone to rancidity when insufficient care has been taken to thoroughly dry the nuts at harvest time. A large proportion of the imported in-shell nuts are of the variety 'Oregon Barcelona', which has relatively large, attractive nuts. However, this variety is slowly being superseded by 'Ennis', which has an even larger nut.

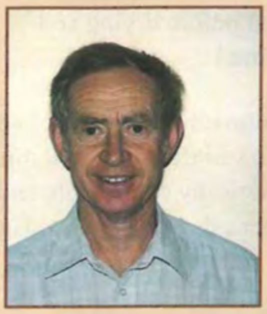
Those growers who plan to sell into the kernel market need to

Table 2. Climatic data from major hazelnut production areas overseas compared with Australian localities where hazelnut groves have been successfully established.

Climatic data	Location						
	Overseas			Australia			
	Samsun, Northern Turkey	Nola Campania, Italy	Corvallis, Oregon, USA	Healesville, Vic	Myrtleford, Vic	Orange, NSW	Deloraine, Tas
Latitude	41°N	41°N	45°N	38°S	37°S	34°S	41°S
Mean annual rainfall (mm)	739	1014	1084	1020	903	901	1087
Hottest month							
Mean max (°C)	26	30	27	27	28	25	23
Mean min (°C)	18	18	11	12	12	12	10
Mean rain (mm)	38	29	14	61	45	109	45
Rain days	4	4	3	7	5	9	8
Coldest month							
Mean max (°C)	10	12	7	12	14	9	11
Mean min (°C)	3	5	1	4	1	0	1
Mean rain (mm)	74	111	173	87	106	87	126
Rain days	10	11	19	16	14	14	17
Harvest month							
Mean rain (mm)	61	79	38	64	60	50	73
Rain days	6	5	6	8	6	7	10

Source:Climatic Averages, Australia 1988, Bureau of Meteorology, AGPS, The World Weather Guide by Pearce and Smith, 1990 talk to buyers or potential buyers to ascertain whether any particular characteristics of kernel size, shape, texture, taste and blanching or roasting flavour are being sought. Some processors have very specific requirements for their products.

About the author



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Hazelnut kernels are covered with a skin or pellicle, which varies in thickness and appearance between varieties. The pellicle can be readily removed from some varieties by a process known as blanching, which involves heating kernels for 10–15 minutes at 135°C, followed by brushing off the loose pellicle to leave a clean white kernel. Varieties that blanch well include 'Tonda di Giffoni', 'Willamette' and the Australian selection, 'Tokolyi/ Brownfield Cosford'. Roasting involves heating for a longer period. The flavour and crunchiness of kernels are increased by roasting. Although some varieties do not blanch well, they are highly prized for their flavour. "Tonda Romana' is such a variety.

Most of the early hazelnut introductions into Australia were as nuts. As the species is cross-pollinated, these nuts were not true to varietal type. Local selections have been made from these early introductions, some of which have been found to be useful, e.g. 'Wanliss Pride', 'Tokolyi (or Brownfield) Cosford' and 'Tonollo'.

During the last 10 years, many individual growers and propagators have imported varieties from the USA and Europe, but extensive evaluations of these have not yet been made.

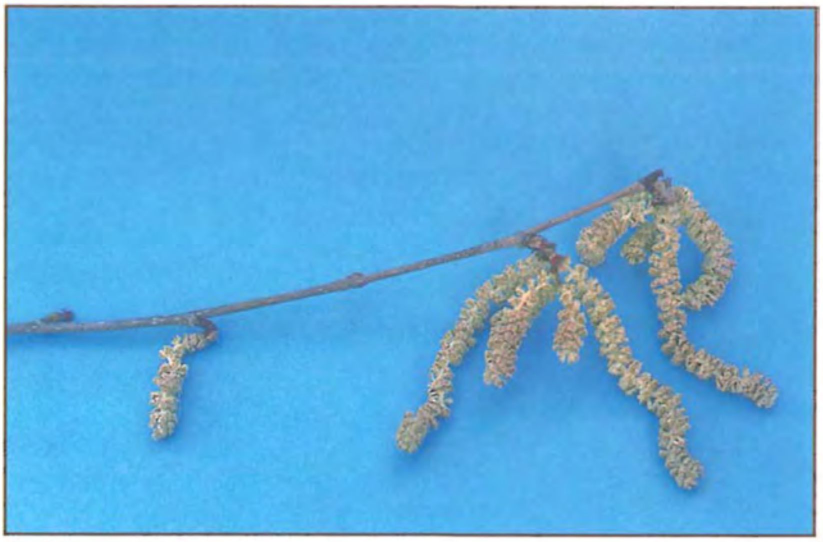
Summaries of the characteristics of Australian and promising overseas varieties are given in Table 3.

Cultural practices

It is important to select a sheltered planting site, as hazelnut trees are very sensitive to wind damage, particularly in the establishment years. It is advisable to plant shelter belts around a proposed site two or three years ahead of planting the grove.

It is generally advisable to apply lime one year before planting to sites which are acid, to bring the soil pH up to about 6.5. Ripping the planting rows in the autumn of the planting year is beneficial on soils that are prone to compaction. Rotary hoeing or cultivating the planting row will loosen soil and provide an environment that favours root growth.

Groves are commonly planted at a density of 300–600 trees/ha, with a spacing of 5–6 m between the rows and 4–6 m between trees within the rows. The more vigorous varieties are planted at the wider spacing. It is essential to keep plantings free of weeds and highly advisable to mulch around the base of young trees to promote moisture retention and



Pollen that is shed from the elongated catkins is blown through hazelnut groves to cross-pollinate the receptive female flowers.

lower the soil temperatures in summer. It is very important that young trees receive adequate water. Supplementary irrigation may be required if rainfall is insufficient.

Key statistics

Imports of hazelnut kernels 1995–96

Total quantity	1829 t
Purchase cost at source	$8.3m
Unit value at source	$4.53/kg (kernel)

Hazelnut varieties produce suckers to varying degrees. These suckers produce very vigorous growth and must be removed two or three times each year, in order to avoid restricting the growth of the productive part of the tree. Suckers are removed either by hand or by chemical spraying.

Hazelnut trees are cross-pollinated. The male catkins, formed during late summer and autumn, elongate in winter and shed pollen which is carried on the wind to the small female flowers. When receptive, these female flowers appear as small buds with reddish filaments (stigmas) at their tips. Both catkins and female flowers are borne on the same plant, but hazelnuts are not self-fertile. Although pollination occurs in the winter, fertilisation does not take place until early summer when the seed (kernel) develops within the shell. The mature nuts ripen in late summer and, in the American and western European varieties, fall from their husks to the ground. (The Turkish varieties do not fall free from the husk and are harvested by hand before drying and threshing.)

For pollination to be effective, the two varieties involved must be genetically compatible and their periods of pollen shed and

Table 3. Characteristics of some important overseas and Australian hazelnut varieties.

Variety	Country of origin	Growth habit	Av nut wt (g)	Characteristics of nuts and their uses	Principal pollinators
Barcelona	USA	Upright, vigorous	3.6	Moderate blanching, principally in-shell	Butler and Halls Giant
Butler	USA	Upright	3.6	In-shell market and pollinator	Barcelona, Ennis and Hall's Giant
Cassina	Spain	Moderate vigour,	1.9	Little pellicle, poor blanching	Hall's Giant
Ennis	USA	Erect, vigorous	4.3	Large nut for in-shell market	Hall's Giant and Butler
Hall' s Giant or Merville de Bollwiller	Germany	Upright, few suckers	3.6	Large nut, principally a late pollinator for many varieties	Ennis and Cassina
Tonda di Giffoni	Central & Southern Italy	Moderate vigour	3.1	Excellent blanching, used in confectionery	TGDL and Willamette
Tonda Gentile delle Lange (TGDL)	Italy	Vigorous, moderately erect	2.6	Excellent blanching, excellent confectionery variety	Tonda di Giffoni
Tonda Romana	Central Italy	Upright spreading	3.0	Poor blanching, but little pellicle, good quality for confectionery use	Barcelona, TGDL and Tonda di Giffoni
Willamette	USA	Moderate vigour	2.8	Excellent kernel variety, very productive in USA	Tonda di Giffoni and Hall's Giant
Australian selections					
Tokolyi/Brownfield Cosford	Aus	Vigorous, spreading, upright	3.1	Kernel blanches well, very crunchy	Uncertain
Tonollo	Aus	Mod vigour	3.4	Sweet kernel, blanches well	Uncertain
Wanliss Pride	Aus	Low vigour,bushy		Large nut, sweet kernel for in-shell market	Uncertain

stigmatic receptivity synchronous. The genetic compatibility of overseas varieties is known and can be used by growers to select appropriate varieties for effective pollination. The variety 'Ennis', for example, which is grown for its high yield of large nuts, is pollinated by the varieties 'Butler' and 'Halls Giant'. 'Butler' sheds its pollen earlier than 'Halls Giant'. These two varieties more than adequately cover the period when the female flowers of 'Ennis' are receptive. Both 'Butler' and 'Halls Giant' produce many catkins and copious quantities of pollen.

The selection of appropriate pollinators is a critical aspect of hazelnut production. A ratio of one pollinator tree to nine main crop trees is generally recommended to ensure sufficient pollen is spread through the grove.

Pests and diseases

Hazelnut producers overseas have to contend with many pests and diseases but, thanks to strict quarantine regulations, most of these have so far been excluded from Australia. Nevertheless, hazelnut blight (*Xanthomonas corylina*), an important bacterial disease of hazelnuts world-wide, does occur in Australia. It was first detected in Victoria in 1980. Blight affects young trees mainly, causing dieback of new shoots and reddish brown lesions (1–3 mm diam.) on the leaves. The husks of infected nuts also have reddish-brown lesions on them and some staining or discoloration of the nuts themselves can occur. The disease is favoured by wet weather in spring and seems to be more prevalent at sites where trees are exposed to strong winds. The rubbing of leaves under windy conditions causes damage to the leaf surface, which allows bacteria to enter and blight to develop.

Key messages

- Hazelnuts are a cool climate crop.
- Hazelnuts valued at more than $7m are imported annually into Australia.
- Current Australian production of hazelnuts is virtually negligible.
- Hazelnuts have great potential as an Australian crop, but more research is required.
- Long term potential exists for export to northern hemisphere countries.

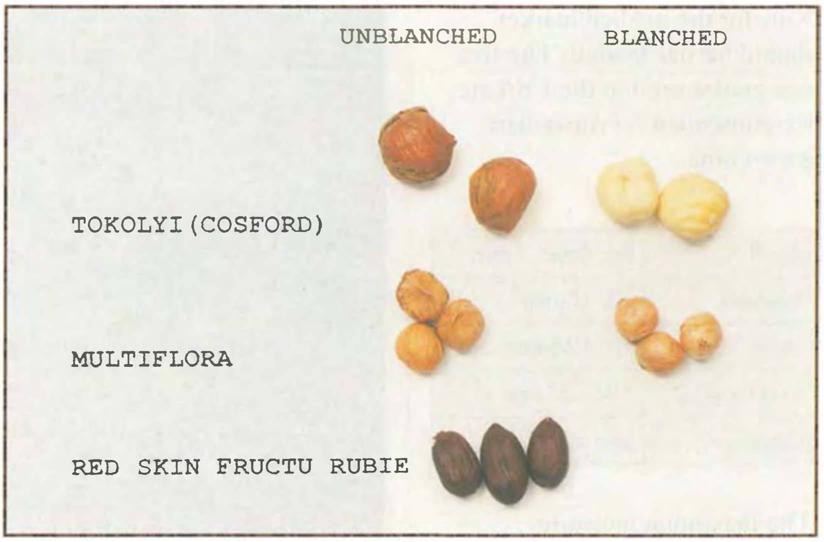
The principal method of blight control is through the application of protective copper-based sprays such as copper oxychloride.

Aphids are often found on the undersides of hazelnut leaves. These small, greenish insects suck out the sap of the plant and can affect development when aphid populations are high. Sooty mould fungus develops on the honeydew excreted by the aphids, causing an unsightly black discoloration of the leaves, nuts and wood.

Foxes can be a major pest at harvest time, as they pick up the ripe nuts from the ground and crack them in their powerful jaws. Sulphur-crested cockatoos have also caused major problems in some Australian groves.

Harvest handling and postharvest treatment

In most commercial varieties, nuts fall freely to the ground, with their husks remaining on the tree. In small groves, nuts are often picked up by hand,



Hazelnut kernels are covered with a skin or pellicle. In some varieties it can be removed by blanching.

but as this is a relatively slow process, mechanised or partly mechanised systems are usually employed. There are three types of mechanical harvesters—sweep and pick-up, vacuum, and fingerwheel harvesters. The sweep and pick-up method is fast, but expensive and dusty. Vacuum harvesters are of intermediate price, but are relatively slow and noisy. In large overseas groves, sweeping machines are used to windrow nuts which are picked up by a vacuum sweeper. Some vacuum harvesters have hand-held hoses that operators use to suck up the fallen nuts. Fingerwheel harvesters are relatively cheap and have considerable potential, particularly for smaller groves. The fingers flick the nuts up into a collecting basket.

It is important to have a level, smooth and firm soil surface in the grove at harvest.

Nuts that are dirty should be washed. All nuts should be dried to a moisture content of 5%, as soon as possible after harvest. Nuts at this moisture content will keep satisfactorily for 12 months.

Nuts for the in-shell market should be size graded. The five size grades used in the USA are recommended for Australian grown nuts:

Small	less than 13 mm
Medium	13–18 mm
Large	18–19.5 mm
Very large	19.5–22 mm
Giant	over 22 mm

The maximum moisture tolerance is 5%, as is the maximum tolerance for blanks (empty shells).

For the kernel market, nuts are cracked and size graded. Kernels produced by the major exporting countries are subject to stringent quality specifications. There is a zero tolerance of rancid and mouldy nuts and foreign material.

Economics of production

The main costs incurred in establishing a hazelnut grove are land preparation, purchase of young plants and installation of an irrigation system. Typical establishment costs are:

	$/ha
Lime application 5 t/ha @ $60/t	300
Land preparation, fertilisers and weed control	250
400 trees @ $12/tree	4800
Micro sprinkler irrigation system[a]	2000
Total	7350

[a] Assumes water supply to the site

Little production occurs before the fifth year, with nut yields rising steadily over the next five years. Assuming a nut yield of 1 t/ha/year after the fifth year, the following annual gross margin could be anticipated:

Income	**$/ha**	**$/ha**
Hazelnuts (in-shell) 1 t/ha[b] @ $3/kg		3000
Variable production costs		
Fertilisers	200	
Sucker removal (3 times/year)	150	
Mowing (5 times/year @ $20)	100	
Weed control	50	
Irrigation (application costs)	100	
Harvesting (machine assisted)	200	
Total costs		800
Gross margin ($/ha)		**2200**

[b] Commercial yields of 2 t/ha have been achieved with the variety 'Ennis' in Oregon, USA.

Hazelnut trees produce suckers which need to be removed. In nurseries, suckers are used for varietal propagation.

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Pistachios

Ben Robinson

Introduction

Virtually all pistachio nuts consumed in Australia were produced in Iran or California, until 1994 when Australian production jumped from approximately 10 t to approximately 70 t. Only those Australians whose origins were in southern Europe or the Middle East or who had travelled in these areas had experienced the delights of the 'smiling' nut. There were no opportunities to eat the nuts freshly picked as they are too perishable to ship half way round the world.

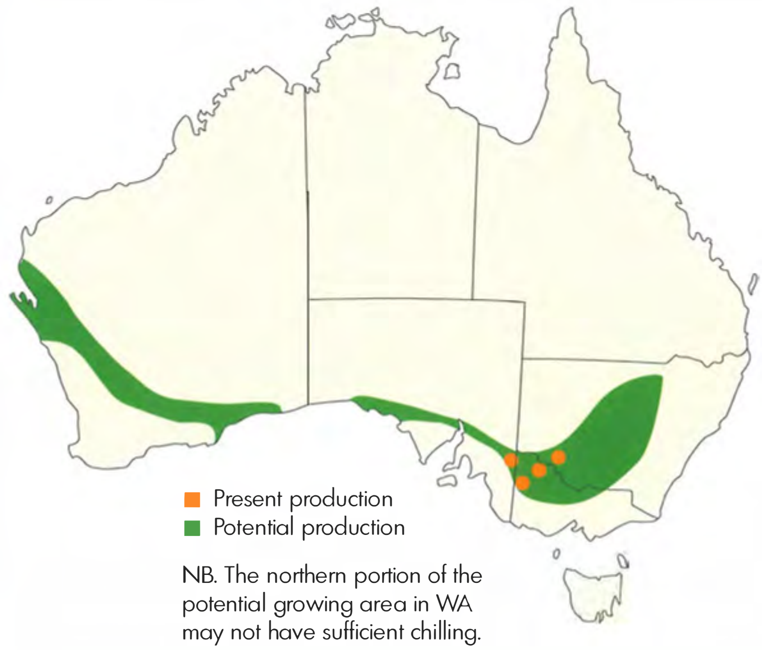
There were early introductions of pistachio trees into Australia (NSW) in 1935, but it was not until the 1960s that a serious effort was made at CSIRO's Merbein laboratories to adapt the crop to Australian growing conditions.

Among the potential strengths of the industry are the fact that pistachio is a new crop; hence, there is an opportunity both for import replacement and to introduce the nut to many more consumers. A full-scale hulling and drying capability (Pioneer Pistachios) has recently been developed which allows rapid processing and drying to achieve top quality. There is good industry cohesiveness.

Perhaps the most important constraint on the industry is the fact that marginal winter chilling is experienced in southern Australia in some years and this results in delayed flowering and low crop. An unidentified limb and trunk canker has been noticed over the last four years in plantings as they reach maturity. Potential growers should recognise that rapid access either to the market (for fresh product) or to a huller/dryer is absolutely critical.

Most pistachio nuts produced in Australia are sold as dried, salted and roasted nuts. This market has been growing at about 10% per year as supermarkets place pistachio nuts in their produce departments. There is a niche market in the larger cities for fresh nuts, which are sold through the market system or directly to specialist greengrocers. The nuts in this form are very perishable. This market can be expected to grow slowly.

The major areas of commercial pistachio orchards are along the Murray River in NSW, Victoria and SA, but there are other orchards scattered through southern and central NSW, Victoria and the SA mallee. There is some interest in development of the crop in WA.



NB. The northern portion of the potential growing area in WA may not have sufficient chilling.

About the author

Ben Robinson is a principal of Scholefield Robinson Horticultural Services Pty Ltd. He has worked for the last nine years with major pistachio growers and the Pistachio Growers' Association to help adapt management practices developed overseas to the industry's needs in Australia.

Australian pistachio orchard showing formal tree shape needed to allow access for mechanical harvesting.

Australia's production of pistachio nuts and fruit is only about 25% of current domestic sales.Most nuts for the Australian market come from Iran and the USA. The proportion supplied by each country varies with the price.

The manager of a pistachio orchard should have a good knowledge of the production requirements of deciduous tree fruit or nut crops, together with a high degree of adaptability, because there are some aspects of the management of pistachio that require slightly different approaches. Special knowledge of tree training is absolutely critical in both the establishment and the production phases of the crop, and a potential grower should become familiar with the standard industry practice.

Markets and marketing issues

Currently, Australian production is replacing imports. More than 90% of production is sold as dried, roasted and salted nuts. Dried, non-roasted nuts and fresh product make up the remainder of Australia's production.

Australian production was about 400 t of dried nuts in the 1997 season compared to Australian consumption of around 1500 t annually. The Australian consumption of pistachios has grown from around 500 t in the last 15 years.

Currently, after processing and packing, net farmgate returns are around $4,750–4,900/t. These prices are determined by the world price for the nuts.

Production requirements

Pistachio is adapted to cold winters and hot summers. Pistachio pioneer Don Maggs has defined a climatic band across southern Australia as having potential for the crop. However, in southern Australia, winter chilling in some years is less than is needed by Sirora, the variety upon which most of the industry relies (1000 degree hours below 7°C). Frost close to or shortly after bud burst will severely reduce the crop.

Pistachios are considered to be more salt-tolerant than other nut and tree fruit species grown in Australia. As with all tree crops, they are likely to do better in favourable soil conditions. Hence, soils that are close to neutral in pH, and that have a potential rooting depth of 60cm above clay or lime restricting layers are to be preferred. As is now widely recommended for any horticultural crop, a proper soil survey on a grid of about 100 m will provide a firm foundation for a long-lived orchard. A knowledge of the depth of the potential rootzone, and the textures within it, allows the irrigation system to be properly designed and managed to take account of the readily available moisture held in the profile. Installation of soil moisture monitoring equipment should also be considered.

Most orchards are watered with under-tree sprinklers or drip irrigation systems. Where water is to any extent saline it should not be allowed to come in contact with the leaves of the tree. Salt damage following foliar uptake has been observed in trees irrigated with bore water.

Steep slopes may limit access by mechanical harvesting equipment, and in frost-prone areas care should be taken to ensure that cold air can drain through the orchard rather than pool in low spots and cause damage.

Varieties

The selection work done by Don Maggs and Don Alexander at CSIRO's Merbein Laboratories led to the selection of the cultivar Sirora which is more suited to Australian conditions than Kerman, the main variety grown in California. The pistachio is prone to alternately bearing light and heavy crops and Sirora, while showing a tendency to biennial bearing, shows less extreme swings than Kerman. Sirora appears to have a lower chilling requirement than many of the named varieties. The nut is attractive and tasty, but has the drawback of being slightly smaller than many of the nuts in world commerce.

There is continuing observation of the performance of trees in the CSIRO gene pool and in variety collections on farms which could lead to the selection of additional varieties suited to Australian conditions. If the canker disease currently seen in mature plantings is found to infect some varieties more frequently than others, it is likely that there will be a serious effort made to select varieties which have canker tolerance or resistance as well as being adapted to the low chill conditions of southern Australia.

Rootstocks for pistachio are important for vigour, disease resistance and possibly drought resistance. Early plantings were grafted to *Pistacia atlantica*, and *P. terebinthus*. Many of the more recent plantings are grafted to Pioneer Gold rootstock the seeds of which are imported from California. This is a selection of *Pistacia integerrima*. The Australian industry watches carefully the research carried out by the University of California on the disease resistance, crop performance etc. of various other potential rootstock selections, and in future will no doubt adapt this knowledge to local conditions.

Key statistics

- Imports are about 1,200 t/year.
- Australian production is about 500 t/year
- World production is estimated to be about 440,000 t/year and is increasing.

Pistachio nut imports into Australia 1995–96.

Source	Amount imported (kg)
China	5,287
Iran	649,796
Japan	12,746
UAE	12,500
USA	521,524
Others	3,192
Total:	1,205,045

Sirora nuts from the 1997 season. Characteristics of this variety are that the nuts are light in colour, show even splitting and have a good flavour.

Fresh pistachios are a new treat for the Australian consumer.

Pistachio is almost unique amongst the commonly grown orchard species in having separate female and male trees. The CSIRO workers examined the flowering times of a range of male trees and selected trees that usually flowered and shed pollen about the same time as Sirora. In Australia it seems that there is benefit in using three male selections to ensure that there is sufficient overlap in every season. The variability of winter chilling hours from year to year means that the actual flowering date of the female trees may vary sufficiently from season to season to make the use of a sole pollinator too risky.

Pollen is transferred from the male to the female trees by wind. Currently about one male is planted to each 11 female trees, but it seems that a lower ratio of males to females (4 or 5%) would be quite safe.

Specialist nurseries are able to supply rootstocks or grafted trees if orders are made far enough ahead. Bud wood for field grafting is usually purchased from established growers.

Agronomy

Before establishing a pistachio orchard, the prospective grower should obtain professional advice to be sure that soils, water and geographic position are suitable. A soil survey should be the basis for a professional irrigation design and chemical soil tests the basis for soil amendment and basal fertiliser applications. Trees should be ordered well ahead of time. Some training of management and key field supervising staff is essential particularly in the techniques of grafting and tree training.

Orchard preparation should involve ripping if there are restricting layers and installation of drainage if this is needed.

Orchard design will depend on the inherent vigour of the site. Closer spacing in the row is used to ensure maximum early yield on a per ha basis (6 m between rows and 4 m between trees in the row is a starting point). Some account should be taken of the inherent vigour potential of the site when deciding on spacing. Any steps that can be taken to maximise early yield will be of benefit as the pistachio orchard takes so long to come into production.

Key messages

- Australia has a small but developing pistachio industry.
- The CSIRO selection Sirora is adapted to Australian growing conditions.
- The main production threat is an unidentified canker which causes tree dieback and death.
- Readily available transport to the metropolitan fresh market and to the processor should be a primary consideration when planning a new orchard.

Rootstocks are planted in spring and topped to about 25 cm. Stakes (usually 5 cm × 5 cm hardwood and about 1.6 m long) are driven alongside each tree. The rootstocks can be budded in the field in January or February if sufficient vigour has been obtained. During the first year of growth some summer pruning is needed to ensure that a suitable trunk can be established. After the bud has been inserted there is an accepted routine of heading back the rootstock which is well described in the US Pistachio Production Manual. As the scion grows it is tied securely to the stake with poly-tape.

The main emphasis in the early years of a pistachio orchard is on the training and pruning of trees. This is more crucial than with most other tree crops. In a large orchard the objective is to ensure that the trees are suitable for mechanical harvesting. In a small orchard which may be too small to interest a mechanical harvesting contractor, more rapid and less formal canopy development should be considered.

At the end of the first growing season, the shoot is headed and positions for about three primary limbs are established. These grow during the second growing season. In the second winter trees are pruned to vegetative buds on the primary shoots positioned so that reasonably regular secondary shoots will be produced. These may need tying into position during the second growing season. In the third year tertiary shoots are established. It is only at this stage that the final shape of the tree begins to emerge.

As with any horticultural operation the final size of the planting will have a large influence on the amount of equipment that is purchased and the balance between work that is managed by farm staff or the owner-operator, and work that can be done by contractors. Orchard operations require access to a tractor, a spray plant for foliar applications, a slasher, a herbicide spray unit and pneumatic pruning equipment.

Shake and catch harvesting equipment will normally be contracted in once the trees begin to carry a significant crop, which may not be until the 5th or 6th growing season. Hand harvesting is preferred on younger trees. Some growers will strip fruit from young trees to allow more rapid growth of the tree canopy.

Soil management is usually effected by using a weed-free strip along the tree row maintained with knock down and pre-emergent herbicides, together with a sward between the tree rows maintained by slashing (or in the case of drip-irrigated orchards, allowed to go dormant under the influence of water stress during the summer).

The nutrient requirements of pistachio trees are not too different from those of other tree crops (such as almonds or citrus). Before planting, phosphorus will be needed on many Australian soils. On reasonably well-buffered soils a basal dressing of superphosphate in a band along the planting row will be all that is required for many seasons of growth. On sandy soils more frequent though smaller applications will be needed. As a rule of thumb, on low P soils apply about 0.5–1.0 t/ha to supply a long-term reserve. Potassium will not be needed on all soils but if the site is sandy, as much as 50 kg of actual K may be needed annually by a mature orchard. Sufficient nitrogen is needed to achieve the required vigour. This should be applied during the growing season. Most of the nitrogen used by the pistachio tree is taken up during the portion of the season which follows the grand period of shoot growth (after shell hardening). There seems to be only limited uptake during the postharvest period.

Foliar zinc is applied before the first growth flush has hardened. Pistachio has a higher requirement for boron than most other trees and nuts. If treatment is needed (leaf analysis) a late dormant spray is applied (after bud swell and before green tips are visible) to the trees (2 to 5 kg/ha Solubor has been shown to be safe). Copper deficiency is seen in vigorous orchards. Shoot dieback occurs on the summer growth flush. A preventative spray of copper EDTA at about 0.5 kg/ha has been successfully used.

Bud burst in pistachio occurs in early October, and flowering occurs shortly after bud burst and continues for a week to 10 days.

The first major growth flush continues until about mid-December when shell hardening is complete. A second flush may occur in late December and continue into February. Embryo growth (nut fill) occurs after shell hardening. Before harvest a high proportion of nut shells split (which is desirable). Water stress at this stage can reduce the percentage that do split, so careful irrigation is needed at this time. Harvest is in March.

Pest and disease management

Pistachio trees are known to be susceptible to a number of root, leaf and shoot and fruit diseases. For example:

Verticillium (impact minimised by choice of resistant or tolerant rootstocks)

Alternaria (not recognised as a problem in Australia at this time)

Botryosphaeria (probably present but currently no recommendations for treatment in Australia)

The Californian literature is very helpful in understanding the range of diseases we might expect to see.

The only disease or disease complex that has received any attention from plant pathologists in Australia is an unidentified canker and tree dieback which has been observed on some male trees and on Sirora female trees. It leads to gumming on trunk and scaffold limbs, a dark xylem canker and in some cases pockets of black ooze beneath the bark. The latter is thought to be caused by secondary infection of non-pathogenic organisms.

A bacterium (*Xanthomonas* spp.) has been found by researchers from Agriculture Victoria in some samples and there is some visual similarity to *Verticillium* but neither has been confirmed as the cause.

Pistachio is also known to be host to various plant-sucking bugs and scale insects. Reference to the Californian literature will demonstrate how broad the range of plant-sucking bugs may be. In particular they are known to cause fruit damage, either to the epicarp (hull) or to the developing embryo (eventually the meat of the nut). A research program has been under way for three seasons to try to associate epicarp lesion and nut drop in pistachio with plant sap-sucking bugs in Australian orchards. Recent progress reports from Agriculture Victoria suggest that two native species, Rutherglen bug and Apple Dimpling bug, may be involved. Damage may be caused to the developing embryo by Green Vegetable bug. Losses as a result of insect attack may not be large, as there seems to be a good deal of fruit drop with no specific cause in this species. Research work is in progress.

Harvest, handling and postharvest treatment

Nuts which are to be sold fresh are hand picked, cooled and manually sorted over a belt. A cold chain must be maintained from tree to retail shop if the fruit are to be attractive at the retail end. There is no standardised packing container, and growers are developing different sorts of packages in an attempt to make the product more widely accepted.

Pistachio nuts destined for drying are harvested with shake and catch machines similar to those used for prunes. Nuts are perishable and have a high respiration rate at harvest time so rapid removal of field heat is important if quality and shell colour are to be maximised. Transport to the processing facility should be fast and the nuts should be held in cold storage if there is to be any delay.

Nuts are dehulled in specially designed machinery. They must be dehydrated to about 7% moisture before they are stable. This can be done in batch handling equipment or in more modern continuous flow equipment.

Flotation tanks and gravity tables allow the separation of blank nuts, and hand or electronic sorting equipment allows grading on the basis of colour. An ingenious 'needle picker' separates split from non-split nuts.

A range of different levels of sophistication in handling, packaging and storage exists in the industry which may be related to the scale of the orchard. Some growers handle and pack their own crop with simple equipment and there are processors that provide a hulling, drying and sorting service on a contract basis.

Mechanical harvesting of pistachio in the Murray Valley

Table 1. Pistachio gross margin and sensitivity analysis.

Enterprise Name:	Pistachio				
Region:	Riverland - Sunraysia				
Enterprise Unit:	One hectare				
Planting:	350 trees/ha				
Producing trees:	300 trees/ha				
Note: The difference between the number of planted and producing trees equals the number of males.					
Income					
Production (net of hulling, drying & sorting costs)		2 t/ha @	$4.75 /kg	$9,500	
Gross Income					$9,500
Variable costs					
Pest and nutrient sprays					
Copper EDTA	1	0.5 kg/ha @	$17.00 /kg	$9	
Zinc sulphate	2	2 kg/ha @	$1.00 /kg	$4	
Dormant Solubor	1	5 kg/ha @	$3.20 /kg	$16	
Tractor/application	4	1 hr/ha @	$26.00 /hr	$104	$133
Pruning			$1.00 /tree	$350	$350
Fertilizers					
Superphosphate	1	250kg/ha @	$208.00 /t	$52	
Urea	1	400kg/ha @	$472.00 /t	$189	
Cover Crop	1	4 kg/ha @	$6.50 /kg	$26	
Tractor/application	3	1.25 hr/ha @	$26.00 /hr	$98	$364
Irrigation					
Water		11 ML/ha @	$51.30 /ML	$564	
Power		11 ML/ha @	$12.50 /ML	$138	
Labour		10 hrs/ha @	$12.00 /hr	$120	$822
Herbicides —area sprayed: 40%					
Glyphosate	5	3 l/ha @	$8.00 /l	$48	
Tractor/application	5	1 hr/ha @	$26.00 /hr	$130	$178
Mowing	8	0.75 hr/ha @	$26.00 /hr	$156	$156
Harvesting					
Contractor (shake, sweep, pick up)			$2.50 /tree	$750	$750
Note: The rate for contractor harvesting services will vary according to farm size.					
Bird control				$35	$35
Freight & insurance					
Insurance			$30.00 /ha	$30	
Freight to processor			$35.00 /t	$140	$170
Total production costs					$2,958
Gross margin ($/ha)					**$6,542**
Yield related variable costs ($/t)					**$70**
Non-yield dependent variable costs ($/ha)					**$2,818**

Table 1. (Cont'd) Pistachio gross margin and sensitivity analysis.

Gross margin sensitivity analysis ($/ha)

Price ($/kg)	Yield (t/ha)			
	1	1.5	2	2.5
$4.50	$1,612	$3,827	$6,042	$8,257
$5.00	$2,112	$4,577	$7,042	$9,507
$5.50	$2,612	$5,327	$8,042	$10,757
$6.00	$3,112	$6,077	$9,042	$12,007
$7.00	$4,112	$7,577	$11,042	$14,507

Economics of production and processing

Establishment costs will be similar to those of other orchard crops such as almonds except that the time between planting and first harvestable yield is much longer and this lag means that any serious development will need substantial financial reserves. Table 1 shows a summary of gross margin data for a typical production unit in 1997. A sensitivity table is also presented which shows how returns may be influenced by yield and/or prices received. These data should certainly not be used as a basis for making investment decisions. Much more detail should be incorporated in a proper development budget within the context of a whole farm plan.

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Walnuts

Harold H. Adem

Introduction

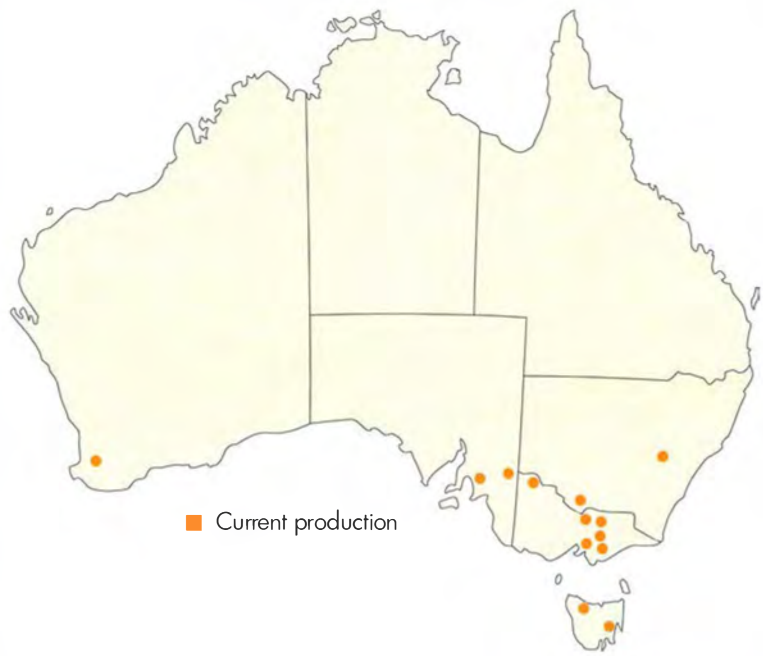
Walnuts appeal to many farmers, part-time farmers, retirees and investors because production is highly mechanised, orchards require low maintenance, are productive for at least 40 years and once harvested, the nuts will keep for two years. Quality walnuts in Australia could return $21,000/ha based on USA average yields of 3.5 t/ha and $45,000/ha based on the best yields.

Many parts of southern Australia have a Mediterranean-type climate ideally suited to the growing of walnuts. The irrigation areas which currently support a highly productive deciduous fruit industry could also support a profitable walnut industry. Compared with the USA, Australia has the advantages of fewer pests and disease of walnuts, clean air and water, and a reduced threat from the urbanisation of agricultural land.

The Australian walnut industry is small producing only 110 t and yet we imported 382 t in-shell and 2115 t of shelled nuts in 1995–96, conservatively valued at $1m and $10m, respectively. Australia can become self-sufficient in walnuts, replace imports, and allow export of quality nuts into the profitable European and Asian markets during winter in the northern hemisphere. In Australia, walnuts have been grown for over 65 years, but the industry is small, with great opportunities for expansion. Walnut trees, managed under the latest technology, will produce nuts in their second or third year and commercial yields in the fourth or fifth year.

Markets and marketing issues

Most walnuts produced in Australia are sold as in-shell nuts, with only a very small percentage marketed as processed (cracked to extract the kernel). Few growers are processing walnuts while in-shell prices remain high (average $4–$5/kg) and where it is difficult to justify the extra cost of machinery. In contrast, the world trade in walnuts is largely in kernels which also reflects the major end-use of the product in the baking and confectionary industries. Currently, most growers market their nuts in-shell and graded into at least four sizes from <25 mm up to >38 mm in diameter which sell for between $3 and $8/kg, respectively. Walnuts are mainly sold at the farm gate, to supermarkets, at produce markets and through health-food shops. A few growers are value-



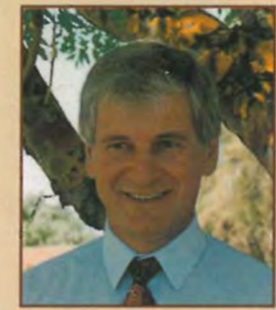
adding by marketing walnuts that have been hand- or machine-cracked, or by selling pickled walnuts. In future, more walnuts may be processed to provide an outlet for damaged and small nuts, or simply to increase the product range and allow the producer to move into the kernel market. The future prospects for Australian walnuts are sound, with prices remaining high in spite of competition from imports from California and China selling for (at times) half the price of the local product. Quality and freshness are the key to marketing Australian walnuts in the face of competition from overseas.

Production requirements

Walnuts require a Mediterranean climate, between 600 and 800 hours of temperatures below 10°C during winter (winter chill), a frost-free period during flowering and during summer maximum temperatures should not exceed 38°C (see map).

Walnut trees are very demanding of soils, especially in terms of texture (the proportions of sand, silt and clay) and structure (the porosity or spaces between soil particles), through which water, air and nutrients move to the roots. Soils need to be soft enough to allow the unrestricted growth of roots and yet stable enough to resist collapse of the structure under wetting and compaction. Deep, sandy loams or clay loams are often favoured for walnut trees. In California, walnut orchards are often located in areas with stable, free-draining loams with topsoils up to 12 m deep.

About the author



Harold Adem, MAgrSc, is a senior researcher who has been with Agriculture Victoria at Tatura (see *Key contacts* for address) for over two decades. He has developed management systems for vineyards and orchards, and a mechanical harvester for the Tatura trellis. In 1992 and 1994 he visited California on study tours of the walnut industry.

In contrast, in south-eastern Australia on shallow (0.1–5m) topsoils overlying a hard clay-pan subsoils, high yields from stone and pome fruit, and more recently walnuts, have been achieved by the adoption of the 'Tatura system' of soil management described later in this chapter. The system provides levels of water, air, stability and mechanical resistance in orchard soils which are non-limiting to tree productivity (Table 1).

Many Australian soils are deficient in nitrogen and phosphorus, and in some soils potassium may also be low. Soil tests to determine nutrient levels are useful to establish broad levels of mineral elements available to the plant, but it is difficult to interpret these results as there are no guidelines for walnut trees. In the absence of absolute values, leaf analysis can be a good guide to the nutrient status of the tree (Table 2).

Irrigation

Walnut trees need approximately 5 ML/ha of water per year during the growing season. Rainfall is

Table 1. Soil specifications which do not limit tree growth.

Purpose	Property	Specification
Controlled traffic	Wheel compaction	<25%
Water management	Matric potential	−10 to −50 kPa
	Levelling index	<1.0 cm
	Aggregate size	>0.5 mm
Root growth	Air-filled porosity	15–20%
	Aggregate size	1–10 mm
	Penetrometer resistance	<1.0 MPa
	Bulk density	1.0–1.3 g/cm^3
Soil stability	Organic carbon	>2%
	Water stable aggregation	>75%
	Clay mechanical dispersion	<1.0%

not reliable enough, in either timing or amount, in rainfed orchards to match the yield and quality of walnuts from an irrigated orchard. The irrigation system adopted at Tatura gives uniformity of wetting, allows automatic watering and decreases the risk of damage to the structure of the soil. Microjet emitters with a 1.3 mm orifice, 40 L/hour output at 200 kPa and a 360° wetting pattern over a radius of 1.5 m are used. Microjets at 3 m spacing, mid-way between the trees will give a continuous wetted strip 3 m wide along the treeline but will not waste water on the traffic line. This gives a precipitation rate of around 4 mm/hour which wets the soil slowly to avoid slaking (crusting) of the soil, minimises soil structure collapse and decreases the risk of waterlogging the trees. In summer, to replace the water lost through transpiration, the orchard is irrigated several times per week. Tensiometers or other sensors in the soil are used to determine when, and how long, to irrigate without waterlogging the trees

Table 2. Nutrient levels (dry-weight) for walnut leaves.

Element	Normal concentration
Nitrogen (N)	2.2–3.2 %
Phosphorus (P)	0.1–0.3 %
Potassium (K)	>1.2 %
Calcium (Ca)	>1.0 %
Magnesium (Mg)	>0 3 %
Manganese (Mn)	>20 ppm
Boron (B)	36–200 ppm
Copper (Cu)	>4.0 ppm

Varieties

Walnuts belong to the order Juglandales, family Juglandaceae. The family consists of six genera, one of which is *Juglans* which includes many species of walnut. The common English or Persian walnut (*Juglans regia* L.) is the main subject of this chapter. Northern Californian Black (*Juglans hindsii*) and Eastern Californian Black walnut (*Juglans nigra*), are both popular as rootstocks for *J. regia* in Australia. Paradox hybrids (*J. hindsii* × *J. regia*) and Royal hybrids (*J. nigra* × *J. regia*) used as rootstocks in the USA because of their increased vigour, are generally not available in Australia.

Chandler walnuts showing the hulls beginning to split exposing the mature nuts.

Up until the late 1980s, 'Franquette' made up 70% of trees planted in Australia, followed by 'Treve Mayette', 'Eureka', 'Myrtelford Jewell' and 'Wilson's Wonder', all of which produce nuts only from terminal buds (Table 3).

In the last 10–15 years, cultivars with lateral bearing habits have been imported from California. The cultivars bred at the University of California, Davis display high fruitfulness (80–90%) on lateral buds, kernel to shell percentage is close to 50%, with over 60% of kernels classified as light-coloured. Presently, the most popular cultivar in the USA is 'Chandler', a heavy bearer producing very high-quality nuts. The cultivar is suitable for dry climates and, compared with 'Franquette', requires less winter-chill to break dormancy. Walnuts are both self and cross-fertilised but the pollen release and stigma receptivity often fail to coincide. For this reason, approximately 10% of the walnut orchard should be planted to pollinators.

In Australia, supplies of grafted trees of many lateral-bearing cultivars are limited because of the scarcity of scion material and the high demand for the available stock. Seed from the Black walnut (*J. hindsii* or *J. nigra*), used as rootstocks, is also in short supply as demonstrated by some nurseries importing *J. hindsii* seed into Australia. The hybrid rootstock Paradox, is rarely used in this country due to its scarcity. Field grafting or budding of the desired cultivar onto Black walnut rootstocks in field nurseries is the traditional method of propagation. An alternative method used in the USA and Australia, is to plant pre-germinated Black walnut seed directly into the treeline in the orchard. The rootstock is grown for one or two years and then patch-budded in mid-Summer. The result is an inexpensive tree which avoids the problem of transplant-shock associated with bare-rooted trees transplanted from a nursery. A further method is to propagate Black walnut seed in pots in a greenhouse using a system of hydroponics. The rootstocks are then grafted or patch-budded in the greenhouse ready to be planted in the orchard at any time once the graft union has taken. Trees produced hydroponically display vigorous growth and a fibrous root system which when planted, establishes quickly to create what is popularly referred to as an 'instant orchard'.

Key statistics

Australian production

	1993–94	1994–95	1995–96
Quantity (t)	86.3	–	110
Tree numbers	32,800	40,300	44,000

Imports

	1993–94	1994–95	1995–96
Quantity in-shell (t)	534	331	382
Value ($A)	1.3m	0.8m	1.0m
Quantity kernel (t)	2554	2180	2115
Value ($A)	14m	9m	10m

Table 3. A description of a selection of cultivars available in Australia.

Cultivar	Pistillate flowers from lateral buds (%)	Blooming	Nut size (g/kernel)	Kernel (%)	Light kernel colour (%)	Shell seal	Nut yield
Franquette	0	late	5.1	46	81	good	fair
Treve Mayette	0	late			78	poor	low
Eureka	0	late			52	good	moderate
Payne	80	early	5.4	48	70	good	high
Hartley	5	late	6.1	45	76	good	high
Serr	50	mid	7.6	58	92	good	low
Ashley	90	early	S.3	SO	75	adequate	high
Sunland	90	mid	9.9	S8	62	good	high
Chico	90	very early	S.0	47	86	good	very high
Vina	90	mid	S.6	48	50	good	high
Amigo	80	early	6.0	52	84	fair	high
Howard	80	late	6.5	50	74	good	very high
Chandler	80	late	6.3	49	96	good	very high
Tulare	80	mid/late	7.3	54	78	good	high
Lompoc	50	early	7.5	54	60	good	high

Agronomy

In the 'Tatura system', to improve drainage and optimise land use the topsoil is hilled into a treeline bank approximately 0.5 m high. From soil tests, the specified amount of lime is incorporated and gypsum spread on the surface in a 2 m wide strip on the treeline. Ryegrass is sown over the entire orchard. To improve drainage through the soil profile, a ripper with a winged-tine is used to till the soil to a depth of 60 cm to create aggregates 1–10 mm in diameter in the subsoil. The nut trees are planted, and the bare soil, created by the tillage operation, is covered with a 2 m wide straw mulch. The following steps are suggested as a guide to setting up a new walnut orchard.

1. In late summer/autumn, peg out the orchard treelines accurately and install the irrigation mains.
2. Use a road grader to move the topsoil from the centre of the traffic line to the treeline to create a bank approximately 0.5 m high.
3. For acid soils (pH < 6.0), apply lime (amount determined by a soil test) in a 2 m wide strip along the treeline, and incorporate with a rotary-hoe.
4. Install irrigation laterals and microjet sprinklers (output 5–10 mm/hour) and irrigate for 2–3 hours.
5. When the soil has drained to around field capacity (2–3 days), cultivate the entire orchard with a tined implement, power harrow or a rotary hoe and smooth the soil surface.
6. For dispersive soils, apply gypsum (amount determined by a soil test) in a 2 m wide strip along the treeline.
7. Sow the orchard to ryegrass or a ryegrass and clover mix and irrigate for 2–3 hours.
8. In late winter, mow the grass/clover sward close to the ground.
9. Use a winged-tine ripper to a depth of 60 cm in three passes in increments of 20 cm.
10. Cultivate the 2 m wide strip with a tined implement, power harrow or a rotary hoe and smooth the soil surface.
11. Plant the trees without compacting the soil and water-in lightly to prevent slumping of the soil. 12. Apply a surface mulch of straw in a 2 m wide strip on the treeline.
13. In spring/summer, use herbicides to control weeds in a 2 m wide strip on the treeline.
14. Slash the orchard and deliver the clippings onto the treeline to supplement the straw mulch.

Key messages

- Import replacement, export potential.
- High yields and early bearing.
- Mechanised harvesting.
- Few pests and diseases.

A field-budded walnut tree showing more than 2 m of growth in one season

Tree spacings commonly used in walnut orchards are 16 × 16 m, 16 × 10 m, 10 × 5 m, 8 × 8 m, 8 × 4 m, 6 × 6 m and 6 × 3 m which gives approximately 40, 60, 200, 160, 320, 280 and 550 trees/ha, respectively. Where spacing within the tree row is less than 6 m, pruning the trees into a hedge will be required from about year five and onwards. Trees that are to be harvested mechanically may need 0.5 m of trunk before branching to allow the attachment of a trunk-shaker.

Pest and disease control

In Australia, there are few pests and diseases which affect walnut production, making the walnut an ideal crop for organic production. In contrast, orchards in California can be affected by more than 20 insects, 10 diseases and nematodes. Codling moth *(Laspeyresia pomonella)*, a major pest of apples and pears in Australia and the USA, is rarely a problem in walnuts in this country but affects crops in the USA.

Walnut blight *(Xanthomonas campestris* pv *juglandis)*, a bacterium affecting flowers, leaves, shoots and nuts, is a major problem of walnuts throughout the world, including Australia. Walnut trees are particularly susceptible at flowering, especially during wet weather in spring and early summer. The disease can be managed in most districts and seasons by spraying the trees with copper-based sprays or by planting late-flowering cultivars.

Phytophthora root rot is a major disease of fruit, nut and ornamental trees the world over. Three species affect walnut trees, namely *Phytophthora cinnamomii, P. cactorum* and *P. citricola.* These fungi are present in most orchard soils and spread quickly through mobile spores when the soil is saturated, especially in warm weather. Infected leaves turn yellow and drop and the trees may die within a few years. Careful soil management and attention to irrigation and drainage will reduce the risk of infection.

Harvest, handling and postharvest treatments

Harvesting nuts by hand is expensive and may account for up to 30–60% of the total production costs. Nut crops are well-suited to machine harvesting due to the presence of a hard shell which protects the kernel from contamination and mechanical damage. Nut harvesters can be classified into two broad categories: shake and catch, and pick-up (from the ground). In the first type, the harvester uses a trunk-shaker to dislodge the nuts and a large apron which wraps around the tree to catch the nuts. In the pick-up type the nuts are allowed to fall to the ground naturally or are shaken from the tree using a trunk-shaker and then picked up from the ground by the harvester.

The shake and catch method produces a very clean sample because there is little contamination from soil, leaves and grass, as the nuts do not contact the ground. The machine will operate irrespective of ground conditions, including where the orchard is wet, uneven, mulched or where there is heavy weed growth. The disadvantages of this method are that harvest losses can occur because nuts begin falling before they can be gathered, or the nuts are harvested prematurely. The operation is slow because time is lost in coupling to each tree and in transferring the nuts from the apron to the hopper. The machinery is inflexible because it is designed for a specific tree and row spacing which then determines the size of the catching apron. The cost of this type of machinery is high (>$100,000).

The shake, sweep and pick-up method is very fast and efficient and, for these reasons, is widely used by nut industries around the world. This method is expensive (>$100,000) because it requires three machines and the orchard must be very smooth, dry and free of orchard litter. Dust, erosion of the soil surface and the mixing together of nuts and litter are inherent problems of the system.

The Tatura system showing 4-year-old trees (6 × 3 m spacing) heavily laden with walnuts.

Vacuum harvesters, using either hand-held hoses or pick-up heads similar to domestic vacuum cleaners, are used successfully in some nut crops. Advantages include an intermediate capital cost (<$10,000), and simple and compact machinery capable of harvesting a range of nuts. Disadvantages include the high labour cost of directing hand-held hoses, slowness of operation, dust problems, noise and damage to the nuts caused by impact while travelling at high speed in the air stream.

Fingerwheel harvesters consist of a roller fitted with plastic fingers arranged in rows similar to the spokes in a wheel, minus the rim. The wheels are often independently sprung, to follow contours in the ground surface. When the roller travels along the ground, nuts are caught between the fingers and carried to the top of the wheels where they are combed out into a hopper. The fingerwheel harvester is simple and cheap ($5000–$25,000), will operate on uneven ground and in grass in the orchard.

Postharvest treatment involves sieving the walnuts to remove sticks and leaves, removal of hulls (hulling), washing, then grading into different sizes. Hand-sorting of nuts is used to remove damaged nuts. The nuts are then put into a dryer to reduce the moisture content of the kernel from 10–30% to around 5–8%. Drying may be done in the sun, in kilns, portable field bins or in fruit bins. In all but the first method, heat applied from a gas or oil burner may be used up to 110°C. Above this temperature kernel quality is decreased. Some growers prefer to use fan-forced air, without heating, to maintain nut quality at the expense of drying time.

In Australia, the highest prices paid for in-shell nuts are for large sound nuts with plump kernels of good taste. In the USA, in addition to the above characteristics, light-coloured kernels bring the best prices because dark kernels indicate rancidity of the oil in the walnut kernel caused by poor handling and storage. Most Australian walnuts are sold in-shell and very few walnuts are cracked and sold as kernel in spite of the potential for value-adding and the bonus of kernel recovered from damaged nuts.

Economics of production

Costs and returns of a new walnut orchard can vary considerably and at best can be considered only as a conservative estimate to be used as a guide for potential growers (Table 4).

The figures in Table 4 are based on a high-density, walnut orchard planted at 6 × 3 m spacing to give 550 trees/ha. The assumptions made are that the land is owned, the Tatura system of management is adopted, lateral bearing cultivars are used and trees are produced by the farmer in pots in a greenhouse. No allowance was made for the cost of the owner's labour or overhead.

Table 4. Costs and returns per hectare for a new orchard ($).

Year	1	2	3	4	5	6	7	8	9	10	11
Establishment	3600	4652	1139	1308	1311	1411	1569	1749	1769	1769	1769
harvesting					193	3S5	481	674	866	1155	1400
Total cash costs	3600	4652	1139	1308	1504	1796	2050	**2423**	**2635**	**2924**	**3169**
Depreciation	82	112	506	506	506	562	480	480	356	356	356
Interest		40	400	400	400	505	505	505	505	505	505
Total costs	36 S2	4804	2045	2214	2410	2863	3035	3408	3496	3785	4030
Production (kg/tree)					1.0	2.0	2.5	3.5	4.5	6.0	7.3
Production (t/ha)					0.6	1.1	1.4	1.9	2.5	3.3	4.0
Income (@ $4/kg)					2200	4400	5500	7700	9900	13200	16000
Net returns	−3682	−4804	−2045	−2214	−210	1537	2465	4292	6404	9415	11970
Accumulated net returns	−3682	−8486	−10531	−12745	−12955	−11418	−8953	−4661	1743	11158	23128

A fingerwheel harvester showing nuts being picked from the ground and collected in bins.

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Plant Fibre Crops

Plant fibre crops

Ian M. Wood
Stuart de Jong

Introduction

The plant fibre crops are those annual and perennial plants from which cellulose fibres are extracted and used to produce textiles, ropes, twines, threads and, more recently, a range of paper products. The most important fibre crop is cotton which is now the dominant plant fibre for the production of textiles. Other important plant fibres in world trade are jute (*Corchorus spp.*), kenaf (*Hibiscus cannabinus)*, roselle (*Hibiscus sabdariffa)*, industrial hemp *(Cannabis sativa)*, sunn hemp *(Crotalaria juncea)*, flax (*Linum usitatissimum)*, ramie *(Boehmeria nivea)*, abaca (*Musa textilis*), sisal (*Agave sisalana)* and henequen (*Agave fourcroydes)*.

These crops are grown specifically for fibre production but there are a number of other crops from which useful plant fibres are produced as a by-product. These include the cereal straws of wheat, sorghum and rice, bagasse (the residual fibrous residue left after the extraction of sugar from sugar cane) and the straw from linseed crops. All these materials are used for the production of building boards and paper.

In this chapter we discuss the potential for the plant fibre crops, other than cotton, jute and abaca. Cotton has been excluded as it is now a major established crop in Australia. Of the other major fibre crops in world trade jute and abaca appear to have limited potential for production in Australia. Jute requires deep fertile alluvial soils and hot humid conditions and there appear to be only limited areas in Australia where it could be grown in competition with current crops. Abaca could be grown where bananas are grown but production of abaca fibre is very labour intensive and difficult to mechanise. Also, cyclones would pose a serious threat to production.

The world production of plant fibre crops for textile use has steadily declined during the past five decades. This is the combined result of advances in cotton production, the development of synthetic fibres, such as nylon and polypropylene, and a decline in the use of sacks for agricultural produce. However, a new use is emerging for some of the plant fibre crops. All the traditional fibre crops can be pulped to make a range of papers comparable in quality with those produced from wood. With the decline in forest resources around the world and an increasing demand for paper, non-wood fibre crops could well be used for this purpose.

Author, Ian Wood, with an experimental crop of kenaf in the Burdekin River Irrigation Area

Markets and marketing issues

In 1994 world consumption of paper and paper board was 268 million tonnes – an average annual increase of 3% since 1988. If this trend continues, consumption can be expected to increase to about 400 million tonnes by 2010 and to about 530 million by 2020.

In 1994-95 Australia imported 191, 000 tonnes of chemical pulp and 1.3 million tonnes of paper and paper board with a total value of about $1.5 billion. At the present time all Australian pulp and paper is made from wood, particularly hardwoods. Currently, about 8% of the world's production of pulp is produced from non-wood materials, including cereal straws, bamboo, bagasse and fibre crops such as kenaf, industrial hemp and sunn hemp.

In Australia the pulp and paper industry has shown little interest in the use of non-wood fibre crops as a feedstock for paper making. However, non-wood fibres are widely used for paper making in India and China and the Japanese pulp and paper industry has recently said that it wishes to produce 10% of its 15 million tonnes from non-wood materials by the year 2000.

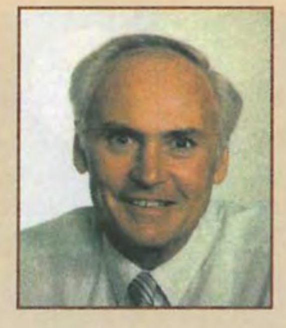
Work in the USA has shown a wide range of uses for the bark and core fractions of kenaf, one of the most promising of the stem fibre crops. For the bast fibre the end-uses include paper, textiles, non-woven earth mats and as a fibreglass substitute. For the core the end-uses include animal bedding, kitty and chicken litter, oil-absorbent mats, particle board (acoustic tiles) and as a component in potting mixes. Similar end-uses could be expected for the other bast fibre crops.

Sisal and henequen are the source of leaf fibres which were traditionally used for twines but are now being used to make high-strength reinforcing pulps which can be used to strengthen recycled paper and paper bags, such as cement bags.

The fibres of jute, kenaf, roselle, sunn hemp, industrial hemp, ramie and flax are present in the bark fraction of the stem and are referred to as bast fibres. The bast fibre crops appear to offer the best prospects for commercial production in Australia with pulp and paper production as the principal end-use. However, other end-uses could be established as subsidiary niche markets. Local or export markets would need to be established for pulp and paper production and it seems likely that the initial development would require an overseas pulp and paper producer. Initially, the enterprise might start by exporting the raw product for processing, but later it should be possible to establish a local pulping facility.

Ramie produces a premium fibre that is used in fine linen and other clothing fabrics. If production and fibre extraction could be fully mechanised there could be a good niche market for the fibre for textile production with any waste fibres being used for high-quality specialty papers.

About the authors



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Key statistics

There is no production of non-wood fibre crops in Australia, other than cotton. In 1994 world production of jute and allied fibres, which includes the stem fibres of kenaf, roselle and sunn hemp, was 3.05 million tonnes grown on an area of 1.86 million hectares. The main centres of production were India (1.53 million tonnes), Bangladesh (0.79 million tonnes), China (0.38 million tonnes) and Thailand (0.17 million tonnes).

Production requirements

Jute, kenaf, roselle, ramie and sunn hemp are all adapted for production over the wet season (i.e. summer) in the semi-arid tropics and subtropics. They are all short-day plants the flowers of which develop as the days shorten to a certain point, which varies with the plant variety. However, temperature also has some influence on the date of flowering. Industrial hemp and flax are also short-day plants but are primarily adapted to spring and summer production in temperate areas.

Kenaf, roselle and ramie are not particularly demanding in their soil requirements and could be grown on a range of soils under dryland or irrigated conditions in the semi-arid areas of NSW, Queensland and the Northern Territory. Sunn hemp could also be grown in these areas but grows best on well-drained, alluvial soils with a sandy loam or loamy texture. Sisal and henequen are cactus-like plants capable of growing on a wide range of soils in the semi-arid tropics and sub-tropics. However, they require a well-drained soil and will not tolerate waterlogged conditions.

The growing of hemp is illegal in all Australian States and imports of seed and hemp products are controlled under the Commonwealth Customs Act 1901. Australia is signatory to a number of United Nations Treaties which refer to international drug controls. Hemp is banned because the leaves of the plant contain the psychotropic drug tetrahydrocannibinol (THC). Industrial hemp is a form of hemp which has been selected to contain less than 0.35% of THC on a dry weight basis. The State Governments in Tasmania, South Australia, Victoria, Western Australia and New South Wales have in recent years all granted licences for experimental sowing of industrial hemp using seed of low-THC varieties imported from Europe. The Queensland Government has recently announced that it will also issue licences for experimental sowing of low-THC industrial hemp. The results of the hemp trials conducted to date in Australia have generally been disappointing as most varieties have given low yields because of early flowering.

Shaun Lisson (see *Key contacts*) in a trial planting of industrial hemp at Cambridge, Tasmania

Varieties

The bast fibre crops are all annuals and their potential yields are largely determined by the date of flowering. For maximum production in a particular location varieties should be selected which start to flower at about the time when the rains stop or the soil water is depleted. Vegetative growth stops soon after the beginning of flowering and this is the optimum time for harvesting whether the crop is being grown for textile fibre or for paper pulp.

Kenaf is considered to be the most promising of the bast fibre crops for the production of paper pulp and a large collection of varieties is held in storage at the Australian Tropical Crops Genetic Resource Centre, QDPI Research Station, Biloela, Queensland. Studies to date have shown that cv. Guatemala 4 is well suited to conditions in northern Australia with Everglades 71 well suited to growing conditions in temperate Australia.

Since production of industrial hemp can only be done under licence and varietal trials have been limited, there are no varieties which can be recommended.

Agronomy

***Kenaf and roselle*:** These are closely related species and have similar cultural requirements. Both grow best under tropical and sub-tropical conditions where mean daily temperatures are greater than 20°C. They are grown from seed at a rate to give a plant population of 300,000 to 500,000 plants per hectare, which requires about 10 to 15 kg/ha of seed. Plant spacing has little effect on yield and inter-row and intra-row plant spacing can be adjusted to suit the available sowing and harvesting equipment. Under dryland conditions the seed is sown as soon as possible after the onset of the wet season (i.e. summer) rains and varieties are used which will start to flower at about the end of the rainy season. Weed control is important in the early stages of growth. As high yields of biomass are produced, the nutrient demand of crops is high and a crop producing 20 t/ha of dry above-ground biomass can be expected to contain about 100 kg/ha of N, 17 kg/ha of P and 220 kg/ha of K. Fertiliser application must be adjusted to meet the expected demand for nutrients.

***Industrial hemp*:** Hemp is adapted to mild temperate climates with an annual rainfall of at least 700 mm. It is intolerant of waterlogging and grows best on a well drained clay loam or silt loam where pH is neutral or slightly alkaline. The crop is sensitive to drought and requires ample water especially during the first six weeks of growth. The optimum temperature range for growth is 14°C to 17°C but the crop will survive short periods of frost. Plant population affects both fibre yield and quality and the optimum plant population appears to be about 900,000 plants per hectare. Sowing date is crucial and should be chosen to maximise the rate and duration of vegetative growth; trials conducted in southern Australia suggest an optimum sowing date of about mid-September.

Good weed control is necessary, especially in the early stages of growth but unfortunately no herbicides are registered In Australia for use with hemp. As hemp produces a large quantity of biomass it has a correspondingly large requirement for nutrients. While the actual requirement will depend on soil nutrient content and the expected biomass yields, European studies suggest that application rates of N, P and K should be about 100-130, 35-50 and 110-140 kilograms per hectare respectively

***Sunn hemp*:** Sunn hemp grows best in the tropics and sub-tropics on well drained alluvial soils with a sandy loam or loamy texture. The optimum plant population is considered to be about 500,000 plants per hectare with 30 cm between rows and 6 cm between plants. This would require a sowing rate of about 25 kg/ha. Cultural requirements are similar to those for kenaf and roselle.

Trial crop of kenaf on the Darling Downs, south-eastern Queensland

Flax: Flax and linseed are the same species but differ in growth habit. Seed flax can be grown under a fairly wide range of conditions but fibre flax needs abundant moisture and cool weather during the growing season. It grows best on well drained loams and clay loams. It is intolerant of salinity and soil pH should be between 5 and 7. Fibre flax requires a clean, smooth, firm seedbed. It is a temperate crop and is sown as soon as possible in the spring. The seed is drilled to a depth of about 2 cm and, depending on the variety, 80 to 110 kilograms per hectare are required. Good weed control is essential as the seed is small and early growth is slow. The crop does not have a high requirement for nutrients but the root system of flax is not extensive and so an adequate level of easily assimilable nutrients is needed.

***Ramie*:** Ramie requires a warm, humid climate with annual rainfall or irrigation of at least 1000 mm spread fairly evenly over the year. While sensitive to waterlogging, ramie is tolerant of soil type but prefers slightly acid conditions with pH in the range of 5.5 to 6.5. Ramie is a perennial having a useful life of 7 to 20 years. It is usually propagated from rhizomes or stem cuttings planted every 30 to 50 cm in rows that are 70 to 80 cm apart. Ramie is usually harvested by hand two or three times per year but under good growing conditions up to six harvests are possible. The highest yield is usually attained in the third and fourth years and maintained until the about the sixth year. For high production a high application rate of plant nutrients is required, particularly of N, P and K. The return of the tops and waste material can substantially reduce the need for added nutrients.

Key messages

- In 1994-95 Australia imported 191 000 tonnes of chemical pulp and 1.3 million tonnes of paper and paper board with a total value of about $1.5 billion
- Fibre crops, such as kenaf, and crop residues, such as cereal straws and bagasse, could be pulped to reduce Australia's imports of paper
- Non-wood fibres may be used in the production of building products such as particle board, plaster board and plastic products, and in geotextiles such as weedmats and insulation products.
- Flax may be grown for use in textile and linen applications. There is also potential for similar applications for hemp. However, with both flax and hemp the quantities required in Australia are likely to be small.

***Sisal and henequen*:** These two species have similar cultural requirements. They are both fleshy perennials with a productive life of 6 to 20 years. The plants consist of a short, thick stem carrying a rosette of long fleshy leaves which are straight and pointed. Both species are stoloniferous and produce shoots from the stolons, known as suckers, which can be used for propagation. However, propagation is usually by means of bulbils which are small buds that develop in the axils of the flower stalk after flowering. The suckers or bulbils are grown on in nurseries until they are about 50 to 70 cm high and are then planted about 1 metre apart in rows 3 to 4 metres apart. Planting is usually done in advance of the seasonal rains when the soil is dry. Rooting is shallow and most roots are concentrated in the upper 40 cm of soil. Permeable sandy loam soils containing some lime are preferred but both species will grow on well drained clay soils. Nutrient requirements will depend on the level of soil fertility and the yield of the crop. Both crops have a high requirement for calcium, nitrogen, potassium and magnesium.

Pest and disease control

Pests and diseases have not proved a serious problem with fibre crops grown to date in Australia. In sowing of kenaf in the Ord River Irrigation Area (ORIA) several loopers, *Anomis flava* and *A. planalis*, caused extensive defoliation of plants but there have been no comparable problems in trials in the Northern Territory and Queensland. A new disease named 'kenaf crinkle disease' which affected the terminal growing point of plants and caused stunting was identified in the ORIA but has not been observed in sowing in other States. Kenaf is susceptible to root knot nematodes but roselle and sunn hemp both have good levels of resistance.

In hemp trials conducted in southern Australia there have been few problems with disease but some problems were experienced with lucerne flea, *Helicoverpa* spp. and black beetle. Both sisal and henequen appear to be free of disease and insect pest problems. Ramie is reported to be subject to a number of pest and disease problems in China, the main producer of ramie fibre. However, no problems were experienced in the limited trials conducted in Queensland.

Harvesting, post-harvesting treatment and processing

The fibre crops have traditionally been produced in countries where labour is abundant and cheap. As a result the production systems have been simple and labour intensive. However, for commercial production in Australia mechanisation is required at all stages from sowing to processing. For the bast fibre crops grown for pulping a number of mechanised production systems have been developed in the USA. Generally, these have involved cutting the crop soon after flowering has begun, laying it in windrows to dry, picking up the dried stems, chopping them into short lengths and then transporting the dried material to a mill. Field drying in windrows is cheap but does pose the risk of picking up soil with the stem material. The sand in any soil that carries through in the pulp is abrasive and can cause rapid wear of processing equipment.

A feature of the stem material of all bast fibre crops is that it consists of two components: bark and core. The bark, which usually comprises about 30 to 40% by weight of the dry stems, contains the long fibres that are used for the production of textiles and high quality paper. The core also contains fibres but these are short and can only be used for low strength pulps and papers. For some types of paper, such as newsprint, both the bark and the core material can be pulped together. For others, it is preferable either to use only the long bast fibre or to pulp the bark and core fractions separately and then blend the pulps back in varying proportions.

Where textile fibre is being produced from kenaf, roselle and sunn hemp the stems are cut at the base, bundled and, after a short period of field drying to allow shedding of the leaves, placed in water for several weeks. During this process, which is known as retting, microbes decompose the non-fibrous material surrounding the fibre bundles so that the fibre bundles can be loosened for extraction. This process is labour intensive and leads to serious contamination of waterways. Attempts to fully mechanise the process have not been completely successful and are generally expensive, making the final fibre non-competitive with cotton and synthetics.

The quality of flax fibre is very dependent on the timing of harvesting, which is generally done when two-thirds of the stem has turned yellow and the leaves have shed. This is usually about one month after the appearance of the first flowers. The plants are generally pulled by hand and allowed to dry in the field. They can also be dew-retted in the field where humidity is high or can be water-retted in ponds. After retting, the plants are dried and the fibre is separated at special scutching mills.

Harvesting trial planting of kenaf with sugar cane harvester at Bundaberg, Queensland

Both sisal and henequen are usually grown in developing countries where labour is cheap and they are harvested by hand. Sisal has a terminal spine which is removed during harvesting. Henequen has marginal spines which make manual harvesting more difficult than with sisal. The rosette pattern of growth makes it difficult to mechanise harvesting. The first harvest is usually done when leaves 60 cm or more in length begin to touch the ground. Harvesting is done at intervals of 10 to 12 months with 20 to 25 leaves being left on the plants after each cut. For paper-making the fibres of sisal and henequen are extracted by first cutting the leaves transversely into pieces about 50 mm long and then passing them through a hammer mill. The fibres are then separated from the juice and residual cell material and dried.

Potential use of non-wood plant fibres in Australia

Textiles. There is interest in exotic plant fibres for apparel, and hemp is certainly a fashion item. However, the current interest is subject to the variable demand of any fashion item. For apparel applications, fibres thicker than 25 microns are considered too coarse and fibres shorter than 25 mm are considered too short.

Flax offers the greatest potential as a textile fibre and its fibres have a well-established reputation for length, fineness and durability. Australia imports small quantities of flax for blending with cotton for furnishing fabrics, sheets and canvas, and for making horse rugs. Flax is still commercially grown and processed in Western Europe into fine apparel and linen, although the industry there suffers from a lack of investment in research and development and of modern processing equipment.

Ramie is also suitable for apparel applications and has been imported into Australia in blends with cotton for jeans fabric. It has also been blended with wool for the production of coarse woven fabrics.

The best potential for industrial hemp appears to be for textile fibre and it could find successful markets in applications similar to flax. In prepared form it would attract a price of about $3500/t and preliminary price calculations suggest that it would be profitable to grow and process in Australia at this price. Hemp has similar textile processing requirements and physical characteristics to flax although the hemp fibre is shorter and coarser than flax, making it less versatile. The market for hemp and flax textile fibre in Australia is relatively small, probably less than 300 tonnes per year. If a hemp textile processing facility was set up in Australia, it should be an industry focused on the export market. As the initial quantities of hemp fibre for textile use in Australia are likely to be small, textile fibre production should probably be secondary to its use for the production of paper pulp or building products. Alternatively, hemp fibre could be grown in Australia under contract for export overseas.

Pulp and paper. The process of pulping involves the reduction of the lignocellulosic material to individual fibres while paper making encompasses the various stages of forming the pulp into a sheet of paper or paper board. Conventional pulping comprises three main categories; chemical, semi-chemical and mechanical. The first uses chemicals to dissolve the lignin that binds the individual fibres together while the third uses mechanical forces to separate the fibres. Semi-chemical processes use a combination of chemical and mechanical processes. Chemical processes are used to produce high quality pulps while mechanical processes are used to produce the lower quality pulps, such as those used to make newsprint.

A feature of all the traditional non-wood fibre crops is that the extracted fibres can all be used to produce high quality, high strength paper and paper pulps. The pulps can be blended with lower quality pulps to improve their strength characteristics or they can be used alone to produce high value papers such as banknotes, film and insulating papers. Work undertaken in the USA in the 1950s and 1960s demonstrated that the whole stems or the separated bark of the fibre crop kenaf could be used to make a range of paper products that had characteristics comparable with those produced from wood fibres. Both the stem material and the extracted fibres are now being used to produce pulp and paper in the USA, Thailand, India and China.

Preliminary assessments of the costs of growing kenaf in northern Australia suggest that it could be produced and marketed for pulping at prices competitive with those currently being paid for hardwood chips being exported from Australia to Japan.

Similar assessments for the production of industrial hemp in southern Australia suggest that its potential as a feedstock for the production of paper and particle board is low. Woodchips are currently available at one-third to one-half the price of hemp when prices are compared on the basis of the cost per unit mass of fibre. The advantages which hemp may have because of its longer and stronger fibre are outweighed by the need to cut the fibre to a length of about 2.5 mm to prevent clumping of the fibres during pulping and the almost negligible value of the core material.

Building products. Plant fibres are currently used in the USA as a substitute for wood chips in the production of particle board. They can also be used for insulation in houses. When there was a scare some years ago that rock wool was unhealthy because the particles of the glass fibres could lodge in the lungs, there was some interest in developing a cellulosic fibre insulation batt as an alternative to fibreglass batts. However, a fibrous batt is effective only if its constituent fibres are very thin and evenly dispersed – an expensive process which is likely to make such batts non-competitive with fibreglass batts.

Sisal is used to a small extent as a reinforcing fibre in plaster-boards and decorative plaster shapes in the building industry but cheaper, chopped glass-fibre matting is replacing it. However, some users continue to prefer sisal as they consider it to be easier to handle and less health threatening than fibreglass.

Other end-uses. Sisal tow is currently being imported into Australia at about AUS$500/t in the form of fibres one to two metres long for the manufacture of twine or rope. Tow is the fibre removed during the combing and brushing of the extracted fibre. However, the use of sisal for rope and twine is steadily being replaced by polypropylene and nylon. Small niche markets exist for sisal twine under eco-friendly farming systems but the declining demand can be expected to be met increasingly by imports of the finished product. Sisal is used to a limited extent as mattress and upholstery stuffing and here it competes with recycled textile waste fibre.

Australia imports jute 'caddy' at about AUS$300/t for use in carpet underlays or in soil matting for weed and erosion control and revegetation. Jute caddy consists of the short waste jute fibres collected during the processing of the longer fibres to yarns. Jute carpet underlays compete with recycled rubber and foam products and are preferred in industrial applications. Increasing interest in environmental restoration can be expected to lead to an increasing demand for soil matting but prices are very low and soil mats compete with a range of bark products and hydro- and straw mulch applications.

Kenaf bast fibres are comparable with those of jute and both are too coarse to be used for apparel. However, they are used widely for sacking and carpet backing. Kenaf fibre could be used in soil mats in semi-processed form but this is an extremely low-value application, competing with mulch.

The potential of industrial hemp to substitute for sisal and jute is small because, although suitable, it would be considerably more expensive after taking into account growing and preparation costs and the likely level of waste.

The use of hemp as a substitute for glass fibre as a reinforcing material is unlikely to be cost-effective and its non-uniform characteristics would be a disadvantage. All non-wood fibres vary because of climate, differences between individual plants and the preparatory processing. These variations make the development of rigorous strength standards difficult. The use of hemp as a filler compound in plastic products is also unlikely to be cost-effective, unless there is a need for recyclable plastics, in which case hemp would have to compete with cotton fibre and recycled cotton fibres, which are considerably cheaper.

Economics of production and processing of non-wood fibres for pulp and paper production

While the costs of production and processing depend on a large number of factors including location, growing conditions and the type of end-product, some indicative costs and returns can be given. In the USA growers of kenaf for production of pulp and particle board receive about US$60 per dry tonne (i.e. about AUS$75/t) for kenaf stems. A similar price could be expected for the other bast fibre crops, such as roselle and sunn hemp. Yields will vary according to rainfall or irrigation. In the

Burdekin River Irrigation Area commercial yields of 20 to 25 t/ha could be expected with irrigation. Under dryland conditions in central Queensland average yields would probably be only 6 to 8 t/ha.

If the raw stem material was being exported for pulping it would need to be compressed into a bale, briquette or pellet to facilitate transport and movement into or from a ship or mill. The costs of producing the pellets etc, transporting them to a port and loading them onto the ship would need to be such that the total cost of the product was cost-competitive with wood chips which are currently being exported from Australia at about AUS$130 per dry tonne.

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Spices

Coriander and fenugreek

'New' spices

Max Jongebloed

Introduction

Coriander (*Coriandrum sativum*) is an annual herb that grows to a height of 30–120 cm. It is believed to have originated in southern Europe and was named after the bedbug emitting the same odour. Coriander is extensively grown in India, the former Soviet States, central Europe, Asia, Morocco and Egypt. Production has also commenced in countries like the United States, Canada and Australia.

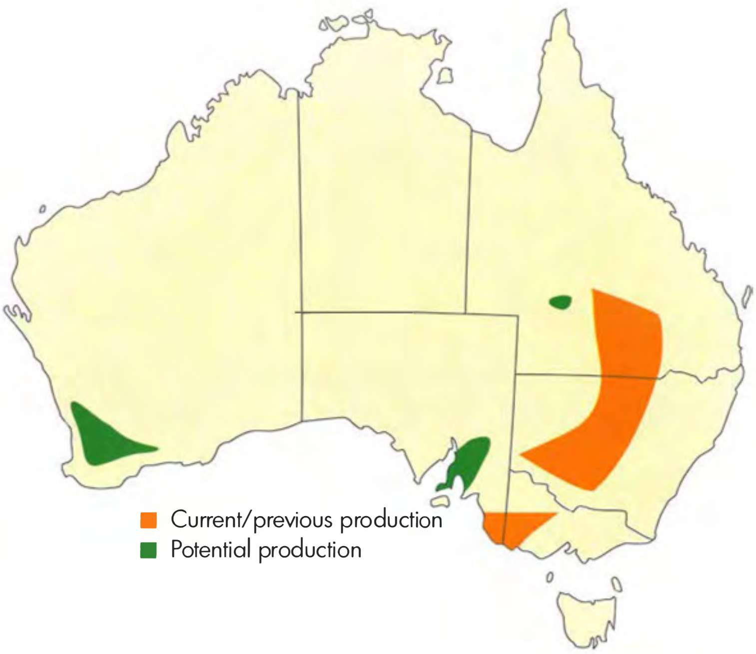
There are two products from the coriander plant that are used for human consumption: the fresh green herb and the seed (spice). The seed is the product that will be discussed here. It is an important ingredient of curry powder and is used also as a pickling spice. In addition, the seed can be processed to extract oil that is used in the alcoholic beverage, condiment and perfumery industries.

Coriander seed is broadly divided into two types according to its size. Seed size is also an indication of volatile oil content and suitability for particular end-uses. The larger seed sizes have diameters of 3–5 mm, while the smaller seeds are 1.5–3 mm in diameter.

The large-seeded varieties are generally grown in sub-tropical and temperate countries (Morocco, India and Egypt) and contain low volatile oil content (typically less than 1%). These types are used extensively for grinding and blending. The smaller seeded varieties are grown in the cooler temperate regions (central and eastern Europe). These varieties produce a volatile oil content of between 0.5–2.0% for which they are highly valued for oil production.

Fenugreek (*Trigonella foenum-graecum*) is one of the earliest spices known to man. Ancient Egyptians used it as a food, medicine and embalming agent. The ripe, dried seeds of a quick growing annual leguminous herb, fenugreek has a strong, pleasant and quite distinctive odour similar to maple. The seed is rich in protein and contains volatile fixed oils.

In India, fenugreek is often used as a cover crop in citrus fruit orchards to take advantage of fenugreek's nitrogen-fixing qualities. India is the major world producer of fenugreek. The spice is exported as whole seed and in powdered forms, as well as in the form of extracted oil, which is extensively used in perfumery.



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Max Jongebloed is General Manager of Seedco, the South Australian Seed Growers Co-operative Ltd which has members in South Australia, New South Wales and Victoria (see *Key contact* for address). The co-operative has been a pioneer in the development of an Australian spice production industry with support from the Waite Research Institute of the University of Adelaide and the Rural Industries Research and Development Corporation.

Coriander seed

Markets and marketing issues

About 90% of the **coriander** produced in Australia is exported, with the domestic market having only limited growth prospects. The main markets for coriander are India, Southeast Asia, North and South America and Europe.

In 1997, the amount of coriander entering the world market was estimated at 40,000 t traded as whole seed. Prices paid for coriander were in the range $A500–$800/t for seed on a cleaned (ex grader) basis. Seedco advises growers to budget on $A600/t ex grader basis with grading and bagging costs amounting to $A60–$90/t.

Seedco provides seed to growers with the seed production delivered to Seedco marketing pools. Private traders also offer contracts, but prices can be very volatile and subject to production levels in major exporting countries. It should be emphasised that price is directly related to the colour quality of the seed.

In 1997, the amount of **fenugreek** exported from India was 8100 t and was valued at US$3.03m. This equates to US$374/t for clean and bagged seed. Growers are advised to seek contracts with grain merchants and overseas traders/ exporters before planting. At this time, this marketing approach appears the only way that growers will be assured access to overseas markets at prices which provide a reasonable return.

Seedco provides fenugreek seed to growers with the seed production delivered to Seedco marketing pools. Private traders also offer contracts but prices are very volatile and subject to production levels in major exporting countries. The major importers of Indian fenugreek are the United States, Europe and Southeast Asia. A very small but ephemeral market also exists for fenugreek seed used as a green manuring crop.

In southern Australia, fenugreek has been commercially produced for a number of years on a small scale. Whilst the potential exists to increase overall production, this can be achieved only with low base prices—typically around $A250–300/t on farm.

Production requirements

The general Australian production requirements for coriander and fenugreek are as follows:

Coriander is suited to a wide range of soil types, with deep fertile loams being the most favoured in the pH range of approximately 5.0–8.0. Soils prone to waterlogging and soils with high iron contents should be avoided. Coriander is suited to a mediterranean climate with wet cool winters and dry summers. It requires a minimal annual rainfall of 400 mm. In most mediterranean climates, coriander is sown at the same time as wheat.

Fenugreek is suited to a wide range of soil types, with deep fertile loams being the most favoured in the pH range of approximately 6.5–8.0. Soils that are prone to waterlogging and soils with a high aluminium content should be avoided. High clay content soils and hard setting soils reduce seed yield due to poor root penetration. Very acid soils are detrimental to plant growth but plants will tolerate mildly saline soils. Fenugreek is suited to regions that receive a minimum annual rainfall of 500 mm.

Varieties

The coriander typically grown in Russia and central Europe (var. *microcarpum)* has smaller seed (less than 3 mm) and contains more volatile oil than the oriental variety var. *vulgare* (greater than 3 mm), which is cultivated for seed and herbage. Varieties that have been commercially grown in southern Australia originate from overseas, as there are no locally bred varieties. The common commercial lines used in Australia are thought to be of Moroccan and Egyptian origin.

There are two well-known Indian varieties of fenugreek. These are 'Desi' and 'Champa'. However, the fenugreek crops grown in Australia are not readily identifiable with any known variety.

Agronomy

Coriander is usually sown during May–June but can be sown as late as July. Seed yield can be reduced from plantings later than July. Treated seed is sown at a rate of 15–20 kg/ha. Optimum row spacing is variable and dependent on whether crops are sown on dryland or irrigated areas. Nitrogen fertiliser is applied as a split dose—as a basal and before flowering.

The ground that is sown to coriander needs to be sprayed with a pre-emergent herbicide. After crop establishment, broadleaf and grass weeds need to be controlled with the herbicides Linuron® and Fusilade®. Weed control is an important issue and needs to be implemented as seed yield and quality (contamination) can be dramatically affected, due to slow growth of plants before flowering.

Fenugreek is sown from mid May to mid June. If the crop is sown later there may be problems of lodging, and seed yield decreases dramatically if the crop is sown later than July. Seed needs to be inoculated with the *Trigonella* strain of rhizobium. The seed should be sown at a rate of 15–20 kg/ha into a fully prepared seedbed. Once again, row spacing is variable and is dependent on sowing time and likely availability of moisture. Nitrogen fertiliser should be applied before flowering commences and phosphorus should be applied at planting if it is required.

The ground that is sown to fenugreek needs to be treated with a pre-emergent herbicide to control weeds. Once the crop is established, weeds need to be controlled with the use of broad leaf and grass herbicides. These chemicals can be Fusilade® for grasses and 24DB for broad leaf weeds. Weed control is very important as this directly affects seed yield and quality (contamination) at the time of seed processing.

Coriander plants

Fenugreek seed

Pest and disease control

No pesticides are registered for use in coriander. Coriander production in Australia has not experienced any major problems from insect pests. However, a few crops have been sprayed to control native budworm.

There are currently two major diseases that affects coriander seed production in Australia—*Alternaria alternata* and *Pseudomonas syringae* pv *coriandricola*.

Alternaria alternata: preventative control of this fungal disease is important, as once this disease becomes evident, seed losses are inevitable. This disease is seed-borne and the best control is to use clean seed lines. This disease is usually transferred from crop to crop. However, it has become common practice to use 2–3 kg/ha of an 800 g/kg mancozeb product at 10% flowering to control *Alternaria alternata*. Fortnightly to three weekly treatments are applied during the flowering period to protect new growth, especially where irrigation is used.

Pseudomonas syringae pv ***coriandricola***: this is a seed borne, bacterial disease against which there is no commercially available preventative treatment.. Research has not yet identified satisfactory control measures. Growers should use only seed that has been tested for freedom from the disease. Growers should use only seed with infection levels below 0.2%. This disease remains dormant in the plant until 'stress' is applied to growing plants (eg. frost, hail damage). Once the disease is evident in irrigated crops, it is suggested that watering cease for 2–4 weeks in an effort to reduce the spread caused by water droplets. The disease can cause total crop loss.

Insect populations in **fenugreek** need to be monitored throughout the life of the crop to minimise damage and reductions in seed yield. Insects that have the potential to damage plants are: red-legged earth mite; lucerne flea; climbing cutworms; heliothis (*Helicoverpa* spp.); blue-green aphid, thrip and Rutherglen bug.

Fenugreek production in Australia has not been significantly affected by disease problems. However, it is subject to: powdery mildew (*Erisiphe polyoni*), blight disease (*Cercospora traversiana*), *Rhizoctonia solani*, *Fusarium oxysporum* (Wilt), and *Meloidogyme incognita* (root rot).

Harvest, handling, packaging and postharvest treatment

Harvesting of **coriander** occurs when all seed bulbs have turned light brown to brown, and the crop is fully mature. Harvesting is undertaken with an open front header, all the while ensuring that the seed bulbs are not smashed and retain their round globular shape. Dryland yields reported by the South Australian Primary Industries Department are 1.1–1.2 t/ha in 450–500 mm rainfall areas while irrigated areas yield 1.8–2.5 t/ha.

No coriander is used in or currently exported from Australia for oil extraction. Nearly all coriander is exported in its whole form and is generally for grinding. Accordingly, all coriander should be free of unmillable materials such as dirt, sticks and stones, and when processed should have a minimum purity of 99.5% (by weight) of whole seed to be acceptable to most buyers.

Whole seed can be packed in woven polypropylene or hessian sacks. Weight of sacks is usually negotiated between the client and seller, as is the quality/type of packaging.

The colour of the whole seed is critical for nearly all markets, with poor colour seeds attracting heavy price penalties or even failure to sell. Good coloured coriander is considered to be very light brown or golden. Poor coloured coriander is usually caused by weather (rain) damage or moisture stress. Weather damaged seed also runs the risk of carrying fungal spores, which are harmful to humans.

With increasing sophistication and demands by overseas markets, growers/sellers of coriander are being required to test spice seeds for contamination and the presence of pathogens such as aflatoxins, and salmonella, coliform and E. coli bacteria.

Fenugreek is harvested when the pods turn brown. The crop is not usually susceptible to shattering and can be harvested with an open front header. Crop lifters are an advantage if the crop lodges or becomes tangled. Expected seed yields are 700–1000 kg/ha for dryland production and for irrigated production 1000–1500 kg/ha.

Like coriander, the colour of the product is important with the preferred seed colour being a light tan/orange. Because nearly all fenugreek is either ground or crushed for the production of molasses to produce a maple syrup substitute, the seed needs to be free of harmful contaminants including unmillable materials. Purity for the spice seed (whole seed) is generally above 99.5%. Packaging and pathology laboratory testing requirements are the same as coriander.

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Fenugreek

Wildflowers

Acacias

Cut flowers and foliage

Margaret Sedgley
Francha Horlock

Introduction

Acacias are recognised overseas as the cut flower crop mimosa, following cultivation over many years in southern France, Italy, Portugal and Japan. Species suitable for the cut flower and foliage industries are those with attractive characteristics including grey or green simple or divided leaves and prolific flowering.

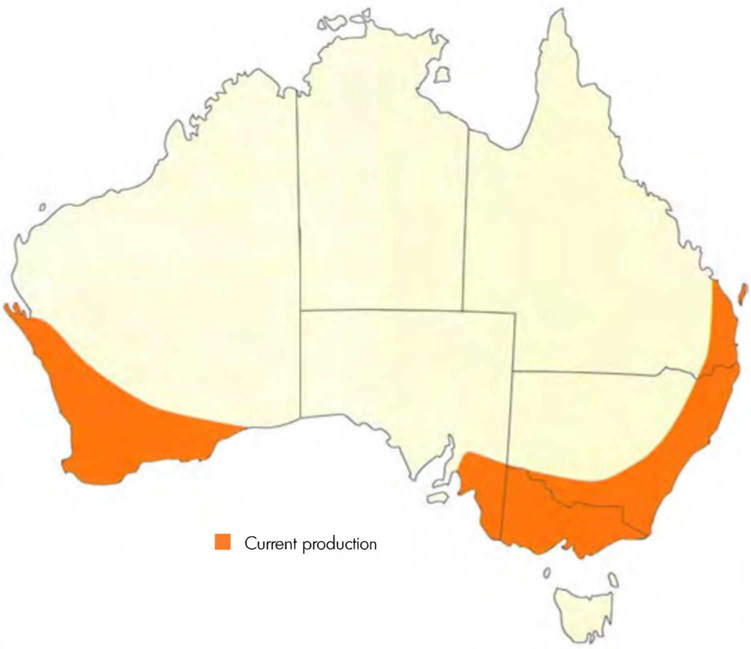
With over 800 species, the genus has wide adaptation to cool temperate, tropical and arid inland climates. Acacias are tolerant of most soil types and have a range of uses. In addition to cut flowers and foliage, they are used for pot plants, tanning, timber, pulpwood, fuelwood, shelter belts, soil amelioration, perfume, fodder and bush tucker.

The main constraint to industry development is lack of cohesion in the cut-flower industry, and reluctance to communicate and co-operate. A further constraint is the lack of superior cutlivars in Australia, which results in lack of uniformity in yield and quality of product. Export of fresh cut flowers and foliage is the area with most potential for expansion.

The most important personal skill requirement for the acacia flower and foliage industry, is recognition of the intensive nature of production. Plant care is essential for quality production and hence for success.

Markets and marketing issues

Asia is the focus of export interest for the developing Australian acacia cut stem trade. The product is familiar to Japanese buyers through import from France, and from local production. Prices for flowering stems are high from September until Christmas, whereas buds and foliage attract lower prices. Pale lemon coloured inflorescences sell best from July to November, with a preference for darker golden flowers from November until Christmas. Europe currently supplies the Japanese market from December to May, providing a window of opportunity for Australian producers between September and December. The heavy odour common in many acacia species is not popular in Japan, where the demand is for more subtle fragrances. High quality and a vase life of a week are essential. Reduction in European exports to the Japanese market from 55,000 stems in 1991 to 23,500 in 1992 are due to poor quality product, and provide an opportunity for Australian producers. The price



for Dutch product is ¥100 to ¥150 per stem (during August 1997, $A1 = ca ¥85).

Mimosa stems produced in France and Italy are marketed throughout Europe, Britain and the USA. The maximum demand period is during the northern hemisphere winter, from the beginning of November to the end of March. Individual growers or regional co-operatives sell either locally, or via central flower markets, from where the product is transported to Holland, Germany, Belgium, USA, UK, Sweden and Switzerland. Export accounts for 70% of the French crop, which had an annual turnover of 40-50 million francs (A$1 million) in 1993. Each market has its own specific requirements, and the industry provides product accordingly.

Key statistics

- Total area of cut flowers in Australia in 1992–93 was 10,114 ha.
- Largest producer of cut flowers in Australia is WA (1269 ha in 1992–93)
- Australian exports of native fresh flowers were over $15 million in 1995–96
- Australian exports of fresh foliage was $541,000 in 1995
- Australia has 8% of the Japanese import market share
- Largest consumers of cut flowers are Europe, Japan and USA

Commercial planting of *Acacia dealbata* in France

The English and American markets require long stems of up to 70 cm with many small branches, the German market demands short branches between 25 and 40 cm for funeral wreaths, whereas the Swiss and Belgian markets accept a mixture.

Production requirements

Most current production is in coastal Australia and is based on relatively few species. Amongst the 800 plus Australian species, there is adaptation to all climatic zones, and production is potentially possible throughout the country (see map).

Many acacias are frost resistant, and within the genus there is tolerance of a wide range of soil types, including pH variation and high salinity. In general, acacias are easy to cultivate, but the cut flower species grown in France and Italy are both frost sensitive and intolerant of heavy soils. Overseas experience indicates that if a species is not adapted to a particular soil type then it can be grafted onto a suitable rootstock. For example, tolerance of the calcareous soils of southern France and Italy is achieved by using *Acacia retinodes* as a rootstock.

Young plants should be watered regularly, and for cut flower production mature plants must be watered to stimulate flush growth following pruning. During summer weekly irrigation is advisable for both young and mature plants.

Varieties

In Australia the species most commonly grown for cut flower and foliage are *Acacia baileyana*, *A. baileyana purpurea* and *A. dealbata*, although many others have potential for cultivation. These include *A. acinacea*, *A. binervia*, *A. boormanii*, *A. brachybotrya*, *A. browniana* var. *endlicheri*, *A. buxifolia*, *A. calamifolia*, *A. cultriformis*, *A. decora*, *A. drummondii*, *A. drummondii elegans*, *A. flexifolia*, *A. glaucoptera*, *A. hakeoides*, *A. imbricata*, *A. implexa*, *A. iteaphylla* (foliage only), *A. leprosa*, *A. longifolia*, *A. mearnsii*, *A. meisneri*, *A. montana*, *A. myrtifolia*, *A. notabilis*, *A. podalyriifolia*, *A. pravissima*, *A. prominens*, *A. pycnantha*, *A. retinodes*, *A. stricta*, *A. suaveolens*, *A. vestita* and *A. williamsonii*. There are no superior cultivars of acacia available in Australia.

Flowering stem of *Acacia decora*

In the French industry, the *A. dealbata* cultivar Mirandole is the most popular, comprising 53% of the market, with the *A. dealbata* cultivar Gaulois at 26% and *A. retinodes* cultivars at 10%. The French cultivars are grafted onto seedling rootstocks.

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Agronomy

Most acacia tubestock currently available in Australia is seed propagated, although methodology exists for vegetative propagation via rooted cuttings. Overseas, acacias for cut stem production are superior cultivars grafted onto seedling rootstocks. Acacias will tolerate most soil types, but very heavy soils should be mixed with sand and organic matter to avoid waterlogging. Before planting the ground is cleared, and the soil ripped to a depth of 40–60 cm. Young trees are planted in rows or along the contour lines of sloping sites, at a spacing of 1–6 m between and within rows. Planting is done in late autumn, or early spring in frost-prone areas, and cover crops are often grown.

Some work has been done to investigate glasshouse production of flowering *Acacia* stems, to avoid problems such as frost and bushfire. Sand, peat and gravel is used as the soil medium, with liquid fertiliser. A further advantage is that the plants flower three weeks earlier than outside, but there are also disadvantages, mainly in the increased incidence of disease problems.

In France, fertiliser is incorporated into the ripped soil before planting, at a rate of 500–1000 kg superphosphate, 150–200 kg potassium sulphate, 150–200 kg ammonium sulphate, 1000–2000 kg vegetable waste and 40–60 t manure/ha. After planting, ammonium sulphate is applied throughout the year after each pruning, and the fertiliser regime for mature plants is 0.6 kg superphosphate, 0.2 kg potassium sulphate and 0.4 kg ammonium sulphate per tree. Iron chelate is used to combat chlorosis in alkaline soils.

Regular pruning has long been used in southern France and Italy, both to control plant size and to induce flowering for specific cut-flower markets. Pruning of old wood is particularly important, as the flowering stems produced on old wood are inferior to those on new wood. Advancement or delay of flowering is achieved in the French mimosa industry by pruning, which serves to promote maximum flowering through the production of many lateral shoots. Pruning of the winter-flowering species *A. dealbata* involves thinning out and heading back at or shortly after harvest. For the summer flowering *A. retinodes*, more frequent and severe pruning is required to delay flowering until winter. This involves repeated heading back of two-year-old shoots to four or five buds to stimulate many fine shoots which will bear the flower buds. The first commercial cut-flower harvest is taken from three-year-old trees, with peak production at six years. Yield per tree varies from 10 kg for *A. retinodes* to 20 kg for *A. dealbata*.

Pest and disease control

Wood borers are the most serious pests of acacias in Australia. Larvae of beetles belonging either to the family Cerambycidae, the longicorn group, or to the family Curculionidae, the weevils, are most commonly responsible. Their presence is detected by frass at the base of the affected branch, or in serious cases by death. Borers are probably largely responsible for the short life of acacias in cultivation, and should be detected and treated early with injection of alcohol or dimethoate into the hole.

Another potentially serious pest of acacias in Australia is the leaf-eating beetle *Paropsis*, which can defoliate plants within a short space of time. The beetles are controlled with maldison and lead arsenate, but the problem is to know when an attack will occur. Larvae of leaf miners can also cause problems, including those belonging to the family Gracillariidae, such as *Acrocerops plebeia* which is a particular pest of *A. podalyriifolia* in Sydney. These make unsightly tunnels in the leaves which detract from the appearance of the stem and may cause defoliation. Leaf miners can be controlled using systemics such as dimethoate. Other pests of acacias in Australia include scale insects belonging to the superfamily Coccoidea, sap-sucking leaf hoppers, gall-making insects, and the *Acacia* bug, *Eucerocoris tumidiceps*, which causes unsightly black spots on the leaves where it has sucked sap.

In southern France, the most common pests of acacia plantings are psyllids. These sap-sucking insects lay their eggs on the foliage, and the larvae attack the young shoots and leaves. The pest is controlled with parathion and endosulphan. The scale insects, *Aspidiotus hederae* and *Icerya purchasi*, are controlled using white oil or methidathion in cool weather, but in warm conditions the predatory beetle *Novius cardinalis* is effective in controlling *Icerya*. Caterpillars and nematodes have also been reported as minor pests of acacias in France.

Key messages

- Natives exported to Asia, Europe and USA
- Japanese market is undersupplied
- Wide climate and soil tolerence
- Peak industry bodies are AF&PGA and FECA
- Supply northern hemisphere off season

Flowering stem of *Acacia podalyriifolia*

Foliage stem of *Acacia baileyana*

In Australia the main disease problem is *Phytophthora cinnamomi* which causes root or collar rot and leads to death of the plant. In southern France the main problem is *Septoria* rust, which causes a red colouration followed by leaf shed. Copper is used to control the problem. Rotary or manual hoeing is the most common method used to control weeds in the French industry.

Harvest, handling and postharvest treatments

In France and Italy harvesting of cut flower stems, which are put into clean water or preservative solution, is done by hand using saws or secateurs. Some stems are marketed at the green bud stage, but in order to maximise returns most are harvested at the yellow bud stage. Stems are harvested just before flower opening, and the cut stems are forced into full bloom before marketing. They are placed in forcing rooms set at a temperature of 22–30°C and 85–95% relative humidity for 48–72 hours with no light. After forcing, the stems with open flowers are transferred to a drying room at a temperature below 12°C, after which they are graded according to stem length and packed. Bunches of varying sizes are wrapped, and are packed into cartons with details of the producer, the cultivar and the number and weight of bunches.

Flower opening during forcing and post-forcing vase life are improved by a postharvest storage solution containing up to 10% sucrose, 200 ppm citric acid, 200 ppm hydroxyquinoline sulphate (HQS), 50 ppm silver nitrate and 50 ppm aluminium sulphate. Using this solution a vase life of 7 days can be achieved. Alternatively, commercial bud opening preservatives can be used.

In Australia recent research has shown that stems with yellow buds can be forced in a pulse of 1% sucrose, 0.01% detergent such as Agral, and 200 ppm aluminium sulphate for 16 hours at 10–20°C. Open flowers are treated in the same way, but can be pulsed at temperatures of 4–20°C. For transport, flowers should be pre-cooled and disinfested, then packed tightly in a carton. Packing stems in perforated sleeves and inserting stems in floral foam, soaked in flower preservative or chlorine solution, may improve quality. A vase solution of 1% sucrose and 50 ppm chlorine or a commercial preservative increases vase life.

Economics of production and processing

Economic analyses for new crops should be treated with caution, especially as so many acacia growers produce other crops as well. The following production figures relate to foliage for the domestic market. For a farm in South Australia, producing more than 500,000 stems per year and receiving a price per stem of $0.25, the gross farm income in 1995 was $137, 213 for average yields and $151,073 for above average yields. This represents a farm profit of $31, 261 for average yields and $45,121 for above average yields, with a return on capital of 6.6% and 9.5%, respectively. Annual per hectare expenses are estimated at $300 for plants, $150 weedicides, $750 pesticides, $100 power, $100 water, $160 fertiliser, $3000 labour, $1650 machinery hire, $250 fuel, $7500 harvesting costs and $3000 pruning. First grade blooms will return $0.25 per stem, second grade $0.10 and third grade $0.05. Overall annual expenses are of the order of $16,960 per ha, against income of $19,800, with a gross margin of $2840 per ha.

Potential returns from cut flower export to Japan are more lucrative. It is estimated that at a planting distance of 2 m × 3 m, production of 75,000 stems at year 4 would return $45,000/ha. More intensive production at 1 m × 1 m spacing is estimated to return 140,000 stems with an income of $86,400 per hectare at year 4. This is based on a price per stem of between ¥60 and ¥120 in the Japan Auction system or ¥100 to ¥120 for fixed pricing. The grower receives about half of this price after export costs are paid.

Pot plant of *Acacia cometes*

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Banksias

Cut flowers

Margaret Sedgley

Introduction

Banksias are identified internationally as Australian, and this is an important selling point which can be exploited on overseas markets. In addition to their visual attributes, they have other features which will ensure their continued popularity, including long shelf life and variety of colour and form.

The main constraint to industry development is the lack of cohesion in the cut flower industry, and the reluctance to communicate and co-operate. Commercial species of banksias are native to mediterranean climate areas, and thrive in light sandy soils of acid pH. This is probably the greatest current production constraint. Banksias are widely cultivated for cut-flower production in southern Australia, with some production in Israel, South Africa, Hawaii and California.

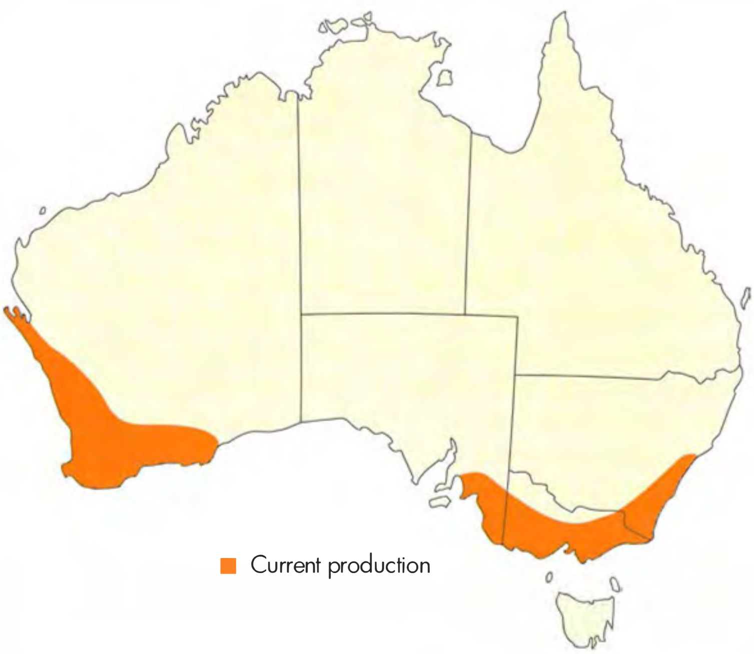
Export of fresh cut flowers is the area with most potential for expansion. The current annual export value of banksias is approximately A$1 million, with half of the production from Western Australia. The largest export destination for fresh flowers is Japan. Germany takes fresh and dried product.

The most important personal skill requirement for the banksia industry, is recognition of the intensive nature of production. Plant care is essential for quality production and hence for success. Cultivation of banksias must be encouraged in place of bush picking.

Markets and marketing issues

The industry is very fragmented, thus placing the individual grower in a weak negotiating position. Most growers of fresh and dried banksias sell to a wholesaler or exporter, although some deal directly with domestic retailers or with overseas importers. Quality standards are currently under development.

Export of fresh cut flowers is the most important and lucrative side of the industry, although some fresh material is sold on the domestic market. There is a smaller demand for dried or dyed blooms, for foliage and for cones. This market is less demanding and generally takes the second grade material unsuitable for the fresh market. For all export markets the quietest demand period is between January and March. Costs of export are high and include costs at the destination, air freight, packaging and quarantine inspection.



The most important export destination is Japan, whose market will pay between $1 and $2.50 per stem. This market is still expanding, as are many other Asian and European markets. Bloom preferences of the various export destinations are important. The USA, Taiwan and Hong Kong prefer dyed banksias, European markets prefer natural colours, and the Japanese like soft, subtle pastels. Most exports to Germany are orange banksias, with 'autumn colours', which are popular for the All Saints festival in November and for grave decoration.

Production requirements

Banksias require a mediterranean climate with high light intensity and long hours of sunshine, low relative humidity and absence of frosts, although some species can tolerate temperatures down to –2°C for short periods. These conditions occur in the coastal areas of southern Australia (see map). Banksias are adapted to soils of low nutritional status, particularly phosphorus, and have a requirement for well-drained acid sands.

Irrigation should be provided throughout the life of the plant, with drip irrigation or microjets the most efficient in terms of water use. Tensiometer studies indicate that, in Australia, irrigation is necessary in all except the winter months. Most of the banksia root system is in the top 15 cm of soil, so regular irrigation is advisable. The plant also has tap roots and vertical sinkers, which can reach down to 7 m to access groundwater. Most banksia growers irrigate twice per week, or three times per week during hot spells. Commonly 4 L/hour drippers are used and irrigations are for 2–3 hours.

Key statistics

- Total area of cut flowers in Australia in 1992–93 was 10,114 ha.
- Largest producer of cut flowers in Australia is WA (1269 ha in 1992–93)
- Australian exports of native fresh flowers were worth over $15 million in 1995–96
- Australian exports of fresh foliage was worth $541,000 in 1995
- Australia has 8% of the Japanese market share
- Largest consumers of cut flowers are Europe, Japan and USA

Varieties

The most widely cultivated species in Australia are the scarlet *Banksia coccinea*, the orange *B. prionotes*, *B. hookeriana*, *B. burdettii* and *B. victoriae*, the green/yellow *B. baxteri* and *B. speciosa* and the pink *B. menziesii*. In Israel, the orange species *B. ashbyi* is widely cultivated. Other species cultivated to a lesser extent are *B. occidentalis*, *B. grandis*, *B. sceptrum*, *B. solandri*, *B. ericifolia*, *B. integrifolia* and *B. brownii*.

There are three named cultivars for cut flower production. 'Waite Orange' is a natural interspecific hybrid between *B. hookeriana* and *B. prionotes*, which flowers between the peak period of the two parental species and so extends the season for production of orange blooms. 'Waite Crimson' is a mid-season dark red selection of *B. coccinea*, and 'Waite Flame' is an early season orange-red selection, also of *B. coccinea*. All are currently being multiplied, and should be available for sale in 1998 from Proteaflora Pty Ltd in Victoria.

Agronomy

Most banksias are propagated via seed collected from the native habitat, but there is an increasing trend toward cultivated seed sources, and vegetative propagation using rooted cuttings. The useful plant life is roughly 10 years. Average yields vary with species from 60 flowers/plant for *B. menziesii* up to over 100 for *B. baxteri*.

Bloom of *Banksia burdettii*

About the author

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Dyed *Banksia baxteri* in Cologne (Germany) Flower Market

Planting is generally done in autumn for the best results, and the area should be cleared of weeds in advance. Between-plant spacings may be 1–2 m for the upright *B. coccinea* to 3.5 m for the more spreading species such as *B. speciosa* and *B. prionotes*. Between row spacings vary between 3 and 6.5 m. Windbreaks are advisable to protect the young plants from damage, and a mulch of a freely-draining medium such as gravel, coarse sand or organic material aids in protection of the roots from extremes of temperature. Weeds should be cleared continually from around the plant, but care must be taken with herbicides because banksia roots are near the surface.

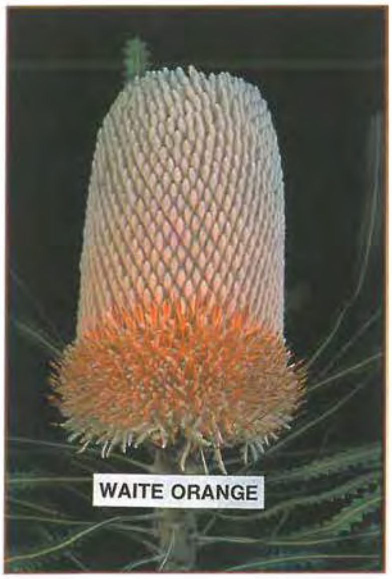
Nitrogen, potassium and iron are important nutrients, but high levels of phosphorus are generally avoided. Fertiliser rates used in Australian flower farms vary enormously, but healthy growth has been recorded with 0.5 g urea plus 0.5 g potassium chloride applied per plant through the irrigation system every 6 weeks, with 1 g ammonium nitrate and 1 g potassium sulphate per week during the active growth and flowering period. Alternatives to potassium chloride should be used where irrigation water is of poor quality, iron chelate is applied when chlorosis is a problem, and calcium nutrition may be an issue in older plants.

Training and pruning of banksias is commenced early and continued throughout the life of the plant. Within a year of planting, the main stem is pruned back to encourage three or four strong, low scaffold branches, which have wide crotch angles and are well spaced around the plant. These are headed back the next year to encourage further branching to form a rounded canopy. At harvest, the blooms are removed leaving four or five healthy leaves below the cut. Immediately following harvest, all thin shoots are removed flush with the stem. This is also the time to remove all two-year-old shoots which have not produced a bloom, once again leaving four or five healthy leaves below the cut so that new branches will form for future harvests. In Western Australia some growers use a hedge trimmer rotation every two or three years. Banksias produce their first crops after 4 years from seed and 3 years from cuttings.

Pest and disease control

Phytophthora cinnamomi, which causes root rot, collar rot or dieback, is the most devastating disease of banksias, as it can result in widespread loss of plants in the field, and can prevent successful replanting in affected areas. The disease is soil-borne, and is readily transmitted on feet, vehicles and tools. It is also transmitted by water, and plants dying successively down a hillside following heavy rain is characteristic of *Phytophthora* infection. Poor growth is followed by drying and wilting of the foliage, as by the time above ground symptoms are visible, the root system has been heavily colonised. In addition to dead roots, there is often stem (collar) rot at ground level. Control of *Phytophthora* is very difficult. Introduction of the disease to a new planting must be avoided, as it is impossible to eradicate the disease once it is established, and it can survive in soil without a host for many years. Chemicals which have been used against *Phytophthora* include phosphonate, fosetyl Al, phosphonate and furalaxyl, but the chemicals may adversely affect banksia plants.

Aerial canker diseases caused by a group of fungi including *Diplodena* are an increasing problem in Western Australia. They can be controlled using clean secateurs and Carbendazin.



Bloom of *Banksia* 'Waite Orange'

Scab or corky bark (*Elsinoe* spp.) causes red, raised scab like lesions on the stems and leaves, which subsequently become corky, and distort growth of the branches. The disease is favoured by moist conditions and moderate temperatures, and it may remain latent in the plant. Removal and destruction of infected material is important. Chemicals which have been used against the disease include mancozeb, prochloraz $MnCl_2$ complex and benomyl.

Tunnelling moth larvae (*Arotrophora* spp.) feed on the flowers. The adult moth lays its eggs on immature blooms and the caterpillars feed on the developing flowers. They move into the centre of the bloom and kill large numbers of flowers by feeding on the soft tissue. The larva pupates in the flower stem. Control is difficult as the larva is protected within the stem, and removal and destruction of infested blooms is essential.

Harvest, handling and postharvest treatments

Banksias are harvested by hand with sharp, clean secateurs to minimise stem damage, and placed into clean water or preservative solution during the coolest part of the day. Care must be taken to avoid bruising and damage to the blooms. The leaves are generally hand or machine stripped from the lower 10 cm of the stem, and in some cases from around the bloom. Blooms are graded according to stem length and quality. Sucrose pulsing does not enhance quality or longevity, and concentrations above 2% are detrimental. *B. coccinea* blooms have a vase life of 15 days in water plus 0.01% chlorine. Hydroxy quinoline sulphate is detrimental. Cold dry storage is possible at 2°C and 100% relative humidity in darkness for 14 days, after which there is a 10 day vase life.

Key messages

- Banksias exported to Asia, Europe and USA
- Southern Australia has ideal climate and soils
- Peak industry body is AF&PGA
- Number of producers and propagators is growing
- Well-drained soil is essential

For natural drying, the blooms are hung until dried, and the process can be accelerated by solar heating, hot air dryers, dehumidifiers, microwaving, freezing and dehydration using silica gel. The colours of both flowers and leaves fade under these conditions. Sulphuring to preserve the colour is achieved either by burning elemental sulphur or by using sulphur dioxide gas in an enclosed area. Stems can be bleached using hypochlorite, chlorite, peroxide or hydrosulphite.

Blooms of pale species can be coloured by dipping into aniline or water-soluble dyes. These impart a wide range of bright colours including blue, purple, orange, red and green, or combinations. Uptake dyes produce more subtle colours but are not much used. Costs of drying and processing are of the order of $0.30/bunch for drying or dyeing, and $0.90/bunch for preserving.

Bloom of *Banksia menziesii*

All live insects must be removed from fresh cut flowers before export. Disinfestation methods generally involve chemical control using methyl bromide, dichlorvos, pyrethrin, permethrin or deltamethrin. Fungicide dips are sometimes used to control postharvest development of grey mould caused by *Botrytis cinerea*.

Cool facilities and rapid transport are essential throughout the marketing chain. The carton should be robust, recyclable, and attractive and display information on variety, supplier and grade. Size requirements differ for the various markets, and the supplier must ensure that the carton size is compatible with containers and pallets in the port of delivery. Liners are sometimes used in the carton. Forced air cooling is ideal, and the carton should have ventilation holes to allow air flow. Refrigerated transport and cool rooms at the point of dispatch and receipt are important.

Economics of production and processing

Economic analyses for new crops should be treated with caution, especially as so many banksia growers produce other crops as well. Indicative figures are that a 5–6 ha cultivated unit is considered the minimum to provide a full-time family living. This represents a minimum investment in the order of $500,000, including the cost of land, cultivation, plants, irrigation, buildings and improvements and machinery. Plant costs alone can amount to over $3000/ha, with irrigation costs up to $3400/ha. Efficiency rises for a larger farm with economy of scale.

Annual per hectare expenses for a banksia farm are estimated at $300 for replacement plants, $150 for weedicides, $375 for pesticides, $100 for power, $100 for water, $150 for fertiliser, $3000 for labour, $1650 for machinery hire, $250 for fuel, $3000 harvesting costs and $3000 pruning costs. First grade blooms will return $0.60 per stem, second grade $0.40 and third grade $0.25. Overall annual expenses for a banksia enterprise are of the order of $12,075/ ha, against income of $20,119, with a gross margin of $8044/ha.

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Blandfordia

Krystyna Johnson

Introduction

The genus *Blandfordia* (Christmas bells) is very distinctive, and is recognised as a monogeneric family Blandfordiaceae. There are four species in the genus: *B. grandiflora* R.Br; *B. nobilis* Sm.; *B. cunninghamii* Lind.; and *B. punicea* Labill Sweet, all endemic to eastern Australia. They are distributed along the eastern coast of Queensland, NSW and Tasmania, with *B. grandiflora* occurring on the mainland and Fraser Island from 24 to 34°S, and *B. nobilis* occurring from 34°S (Sydney, NSW) to approximately 36°S. *B. cunninghamii* occurs in the Illawarra and the Blue Mountains regions of NSW (34°S) and *B. punicea* is endemic to Tasmania.

The natural habitat of the genus has been disappearing since the time of European settlement, and it would seem that the whole genus may be under threat in the wild, since its distribution along the eastern coast of Australia, includes some of the most heavily populated and rapidly developing areas of the continent.

The genus has been exploited as a bush-picked seasonal cut flower crop for many years on the domestic market, and increasingly for overseas markets. Commercial cultivation of *Blandfordia* species began about 9 years ago. *Blandfordia* is among many members of Australia's indigenous flora which are now begining to be cultivated commercially for international and domestic markets).

Blandfordia is a very attractive focal flower, with a wide range of colours, an attractive shape and a long vase life. Eleven types of the flower colour (from red to yellow) and eight different shapes have been identified.

Blandfordia grandiflora is a very slow-growing crop taking at least 3 years to produce its flowers. It has quite specific requirements for soils, water and nutrients. It is also subjected to weed infestation, and requires close husbandry. A good understanding of horticultural practices and postharvest handling is required for produce this crop.

At present the growers from eastern Australia (Port Macquarie area, see map) are the only world suppliers of this novel cut flower variety. It is believed, however, that Zimbabwe, Israel and other countries are now preparing to market *Blandfordia*.

Variety of colours in *Blandfordia grandiflora* selections.

Markets and marketing issues

The formation in 1989 of a group of growers, researchers, advisers and other interested parties known as Blandfordia Research and Extention Group (BREG), has consolidated efforts to develop and market *Blandfordia* as a commercial cut flower. At present, *Blandfordia* is cultivated by a small number of growers in northern New South Wales, and some blooms are still harvested from the wild under licence. Flowers harvested from the wild are sold on the domestic market only. *Blandfordia* flowers during October–January (early summer, Christmas). There is a scarcity of flowers during the northern hemisphere winter, so this product has a ready market there and could earn substantial export income for Australia.

Blandfordia blooms are grown and packed for market on the farm. Those destined for the domestic market are sent directly to agents at the metropolitan flower markets or to local retailers. Flowers destined for export must be carefully checked for quality and freedom from pests and diseases. They are graded and usually fumigated or dipped before packing on the farm, and kept in cool storage until transported to the exporter. They are again checked by Australian quarantine officers before being dispatched to overseas destinations. On arrival, flowers are checked again by the importer's quarantine services before being auctioned and distributed to customers.

Trial shipments of the *Blandfordia* flowers to Japan began in December 1991, and further shipments have been made each year since. The price at the Tokyo flower auction reached $A5/ stem in 1991, with an immediate order for 20,000 stems per week for the Tokyo market alone!

Only cultivated flowers are of export quality and can meet Japan's phytosanitary requirements. The flowers were shipped to Holland for the first time in 1993. Total export production has increased slowly to a total of 50,000 stems in 1996, while home consumption is around 250,000 stems (IHM 1997).

About the author

Krystyna Johnson is a lecturer in urban and environmental horticulture at the University of Technology, Sydney (UTS) (see *Key contacts* for address), with a special research interest in the horticulture of Australian native plants, particularly the genus *Blandfordia*. She was co-editor of the major text, 'Native Australian Plants, Horticulture and Uses', published in 1996 by the University of New South Wales Press.

Production requirements

The natural habitat of *B. grandiflora* are the Moist areas of coastal heathland with an annual rainfall of 1000–1600 mm, and a temperature range of 0–35°C, are the natural habitat of *B. grandiflora*.

The preferred growing medium for *Blandfordia* is a mixture of equal quantities of peat and coarse clean sand. The pH should be in a range 5.0–5.5 and lime and dolomite are used to achieve this.

The water requirements of *Blandfordia* plants of different ages have not been determined, but it has been suggested that older plants require less frequent watering. The plants require adequate water during budding and flowering. Through the summer, daily watering is required. In winter plants are watered less frequently.

Varieties

At present three biotechnology companies are involved in micropropagation and trials of selected clones. These clones were released under contract by the University of Technology, Sydney. New selections are being made and are being micropropagated for future trials. *Blandfordia* is very slow growing, however, and the commercialisation is still very much in the trial-and-error stage. There is still much to be done before production of this crop will meet the market demand.

Other species in the genus also present horticultural potential, but have not been investigated in detail so far. *B. nobilis*, for example, with small bells has great potential as a pot plant. *B. cunninghamii* presents qualities other species do not possess. It has long leaves which droop gracefully and spectacular bells, and would be attractive as a cut flower or pot plant. *B. punicea*, which is endemic to Tasmania, usually has scarlet flowers, finished off with brilliant yellow wings. This species also has cut flower potential.

Table 1. Average prices per stem achieved in Holland and Japan ($A).

Year	Japan	Holland
1994	1.50	
1995	0.50	0.54
1996	0.59 with 1995 ex. rate 0.82	0.58

Source: IHM Pty Ltd (1997)

Agronomy

To date, *Blandfordia* has been grown commercially in 5–7 litre plastic planter bags with 3 plants per bag, but root-binding and crowding is apparent after 4 years of growth. This does not change the frequency of flowering, however, and the number of flowering stems has not fallen.

A new phase of crop development—field production—has just begun. Two-year-old seedlings have been transplanted into beds at densities of 65 plants/m^2. Field production should make the crop more economic, although the initial costs of crop establishment are high.

Protective structures are needed to prevent insect and bird damage to field-grown plants, and ensure quality of bloom.

Key messages

- *Blandfordia* is a unique Australian flower
- Its habitat is under pressure
- Its potential as a cut flower is only minimally utilised
- It is popular with the world markets
- Its cultivation, postharvest and marketing have been researched
- *Blandfordia* is slow to grow, and there are still technical difficulties

Protective structures are needed to prevent insect and bird damage to field-grown plants and so ensure the quality of blooms.

Although *Blandfordia* grow in poor soils in the wild, they do much better under a suitable fertiliser regime and, indeed, their growth is retarded if they do not receive appropriate nutrients. A range of slow-release fertilisers should be incorporated into the growing medium. To maintain good growth, a two-part soluble fertiliser should applied regularly. Regular application of fertiliser at fairly low concentrations, together with slow-release fertiliser, gives excellent results.

Disease control

Blandfordia grandiflora appears to be susceptible to soil-borne pathogens, namely *Pythium* speciesand *Phytophthora* species. Wet conditions and poor drainage must be avoided in the cultivation of *Blandfordia*. Botrytis flower rot has been observed during storage or shipment. It may be caused by hot, humid conditions, the preharvest fungicidal sprays or by storage at too low a temperature.

Helicoverpa armigera (corn earworm), *Epiphyas postvittana* (light-brown apple moth), *Pseudococcus longispinosus* (long-tailed mealy bug), and thrips have been identified as the main insect pests of *Blandfordia*. *Pseudococcus longispinosus* has proven to be the most intractable pest problem to date. Other insect pests encountered are scalea andaphids. Rats may attack corms, especially those in pots and planterbags.

Blandfordia plants do not compete well with other vegetation and can be choked out, with stoloniferous invaders particularly troublesome. Liverworts and mosses can be harmful, especially for young plants. Weed control recommendations are required for future production, based on herbicides, cultivation, and mulches.

Harvest and handling

At present, *Blandfordia* flowers are harvested when one flower per cluster is open, although earlier harvesting is being tried by some growers. The use of floral preservatives such as 8-hydroxyquinoline sulphate (HQS), sucrose and silver thiosulphate does not improve the keeping quality of *Blandfordia* stems picked with one flower about to open or already open. *Blandfordia* stems respond well to cool storage and appear not to be sensitive to ethylene. Flowers can be stored at 1°C for at least 30 days. At

1°C there is no bud opening at 2 weeks. Flowers stored at 1°C kept just as well when packed dry in plastic bags as they did when stored in water. Stems stored at 10°C for 1 week have a vase life of 6 days when transferred to 20°C. The vase life of stems held for 2 weeks falls to 4 days. Stems stored at 5°C for 2 weeks have a vase life of 7 days at 20°C, and 8 days when stored at 1°C. Bud opening is not stopped at 10°C and is only slightly retarded when stems are stored at 5°C . Worrall and Wade (1996) recommend on-farm cooling, forced-air cooling, closure of carton vent holes before shipping and single flower consignments to improve the postharvest cooling and hence product quality of *Blandfordia*:.-

The following points must be considered when presenting *Blandfordia* flowers for export.

- **Flower colour.** From a range of eleven colours 1–11, most are accepted for sale, as the present production comes from the seedling material. When clonal material is available, flowers will be graded by variety. This grading, by definition, will include standardised colour combinations.
- **Flower stem.** Must be free from natural or induced deformities, with good proportions between flower head size and stem length. Currently, the stem length accepted for export ranges from 50–70 cm, with 5–10 mm in diameter. The stem bracts, which vary in number and size are usually removed from the lower flower stem.

Packaging is a major cost in exporting *Blandfordia* at present. The basic system used is a triple pack, comprising three shallow boxes, each holding 40 stems of 70 cm length or 60 stems of 50 cm. Stems are packed in two layers, 20 per layer, with 10 flower heads at each end of the box for each layer. To prevent the movement of the blooms within the box, the stems are clamped together by strips of polystyrene foam, secured with rubber bands and themselves clamped by the pressure of the box top. Flowers are covered top and bottom, both layers, with synthetic wadding. Bubble plastic liners are used on the bottom and top of each box to insulate from temperature extremes, provide shock resistance and retain humidity in the box. Each stem is placed in a plastic sachet holding 15 mL of water. This provision of external water supply during long or short (shipping) storage is not essential, but some importers, such as those in Japan ask for the flowers to be supplied with the sachets.

Economics of production

Blandfordia is a plant of peaty–sandy wet areas of the south-eastern coast of Australia. Its sucessful cultivation has so far been limited to those areas.

An area of 1500 m^2 on current spacing will be adequate, with generous service paths, for some 60,000 plants—probably as many as a family unit could manage. Alternatively, the plants may be established in pots or planter bags of around 6 litre volume with 2–4 plants per bag. A plant density of about 60 per m^2 is recommended. The plants grow in sandy-peat with a pH of 5–6. The most economic planting medium is naturally occurring sandy-peat habitat. A sand–peat mixture can be imported for use in pots/poly bags or raised beds.

Blandfordia , like lilies, require a lot of water (slightly acidic, and low in salt), and a suitable place for their cultivation. *Blandfordia* grow in nature in the understory of heathlands, rarely exposed to full sunlight, so provision of shade is recomended. Thirty percent shade cloth is being used by a number of growers who have felt that 50% was too heavy, and flowers produced under it tended to be pale. Shade cloth also provides physical protection against birds and insects, and reduces wind damage. Fairly light fertiliser use has been the rule, and judicious use of oil sprays and insecticides gives good protection. For harvesting, a cold room and packing shade are requirements. Packaging has been too complex and fairly expensive to date, but changes are being made.

Establishment cost

To get started a new grower will require:

- A suitable area of land with good water
- A system of irrigation (dripper lines are suitable for in-ground plantings, but overhead sprays may be used, especially with pots or poly bags).
- Initial 50,000 plants which can be purchased from reputable nurseries. Selected clonal plants are also available.

50,000 (12–18-months old) seedlings, or de-flasked, rooted plantlets will cost around $10,000.

- A shade house of simple design will cost around $12–15.00/m^2.
- A packing house (about 40 m^2) can be build for about $6000
- Power and water need to be connected
- A cold room (about 2.4 m^2) will cost about $6000
- Tables, benches, stools and sink are also required

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Boronias

Julie A. Plummer

Introduction

Boronias are known for their floral displays and scent. Like so many wildflowers *B. heterophylla* and *B. megastigma* were originally bush picked. Today *B. heterophylla*, and to a lesser extent *B. megastigma*, *B. serrulata*, *B. clavata* and. *B. muelleri* are cultivated for cut flowers. *B. megastigma* is also cultivated for the essential oils in its blossom.

Boronia heterophylla can produce reasonably long stems of vibrant pink flowers. Bushes are quite productive for several years. Postharvest life is adequate and there is strong export demand. The main limitations for expanding boronia production are the restricted flowering period and colour range. *Boronia heterophylla* is the dominant crop both domestically and for export. Unfortunately in most areas the harvest is over within two weeks.

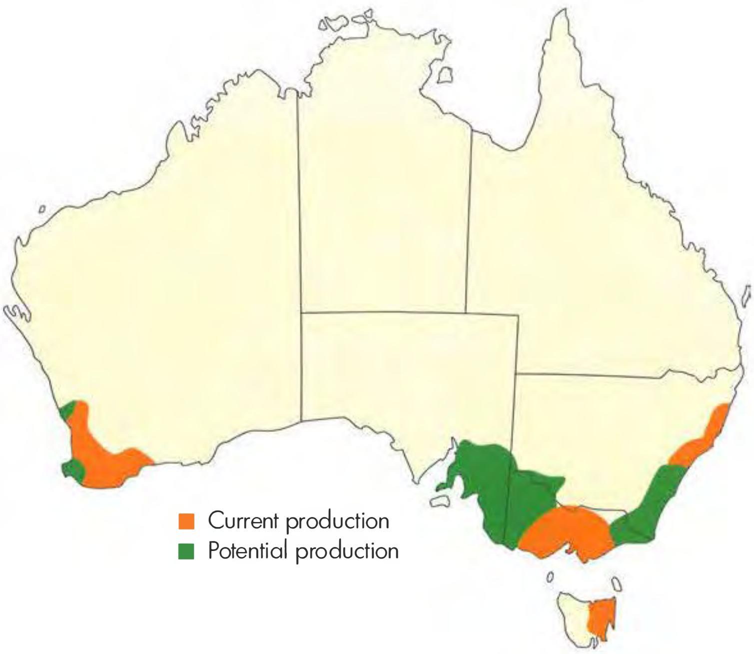
Some varieties of *B. megastigma* are cultivated but the market is much smaller as the postharvest life is short and the perfume is unattractive in Asia, making it unsuitable for export. Production of other species is quite limited. Until recently *B. megastigma* was the only species that had been surveyed for superior varieties.

New selections of *B. heterophylla* have recently become available and more should be released within the next few years. These varieties will offer a greater range of colour and flowering time. Also a breeding program examining a wider genetic base within the genus *Boronia* has begun and this should result in a range of new products. Increases in production are likely to be tied to the demand for new varieties. Access to the USA could also increase demand for Australian product and this is currently being pursued.

Boronias are currently grown for cut flowers on the east and west coasts of Australia, New Zealand, California, Israel and to a lesser extent in South Africa and Europe. They are susceptible to root rots and rust and require good site selection and careful management.

Markets

Cut flowering stems of *Boronia heterophylla* have been exported to Japan for nine years and markets are growing in Singapore, Hong Kong, Taiwan, Europe and Canada. An import ban on Rutaceous species prevents boronia from entering the United States of America. A selection and breeding program at the University of Western Australia, partially funded by RIRDC and Sunglow Flowers



Pty Ltd is currently investigating the possibility of expanding the flowering period and colour range of the flower.

Plant selection

The genus *Boronia* (Rutaceae) is represented throughout Australia and species are found in a wide range of soil and climatic conditions. A range of flower colours and flowering periods exist but only a few species have been commercially exploited. Consult with your exporters, local nurserymen and experienced growers to determine the best varieties for your area.

Boronia heterophylla is an upright shrub 2–3 m tall from Western Australia. It bears a profusion of vibrant, pink, bell-shaped flowers about 1 cm long which provide a spectacular floral display. This species is the most widely grown for cut flowers. The flowering period for individual plants is usually less than two weeks in late September/ early October and flowers fade if left on the bush. Some flower colour selections have been registered including, 'Moonglow' (white), 'Cameo' (pale pink), and 'Lipstick' (mid-pink) and 'Morandy Candy' (deep pink), which may be hybrids. *B. heterophylla* is fast growing and responds well to pruning. It withstands light to moderate frost. Plants prefer dappled shade or partial sun but will grow well in full sun if roots are kept moist and protected.

Boronia megastigma is an upright, dense shrub 1–3 m tall. It is found in wet or seasonally wet sites in Western Australia. Individual plants flower from late July to October. The bell-like flowers are usually dark to reddish brown on the outside and yellow on the inside and are not showy. Flowers are very fragrant. *B. megastigma* used to be extensively grown as a cut flower in Victoria but rust (*Puccinia boroniae*) wiped out the industry. Selections, based on morphological characters desirable for cut flowers, include forms where the outside of the petals are red, such as 'John Maquire's Red', 'Arch Chandler's Red' and its sport 'Harlequin' which has vertical reddish-brown and yellow stripes, and 'Lutea' a yellow-green form. Unfortunately these selections have poor vase-life and do not transport well. The perfume, which is the main attraction in Australia, is less desirable in Asia. Much variation exists in flowering time, flower colour, fragrance, oil content and growth habit.

Boronia heterophylla, 'Moonglow'

About the author

Dr Julie Plummer is a Senior Lecturer in Plant Sciences at the University of Western Australia (see *Key contacts* for address). She has selected boronias which are currently being tried out and is breeding boronias using a range of species.

Boronia muelleri is from the southern coast of New South Wales and Victoria. Flowers are 1.5 cm across and vary from white to pale pink. Flowers are borne on terminal clusters from August to November. At present production is limited.

Boronia purdieana is a small shrub from Western Australia. It bears a profusion of perfumed, greenish-yellow flowers from July to August. This early flowering species has short stems

(30–40 cm) but it is sought after as a cut flower. Cultivation is still limited and in 1993 there were 49,000 bush harvested stems and 900 stems from cultivation. *Boronia purdieana* is from the coastal sandplain north of Perth and it probably requires well drained soils and will grow in hotter/drier areas than *B. heterophylla*.

Boronia pinnata is a small shrub from New South Wales. It bears pink clusters of flowers from August to November. It is largely bush picked and is in demand from florists. It has 5–8 days of vase life. It is difficult to propagate.

Boronia serrata is a small shrub 1.5 m tall from New South Wales which produces abundant rose pink flowers. Individual plants produce flowers for 4–8 weeks but flowering in natural habitats occurs from late July to November. A short vegetative flush occurs from December to January and this can be extended in cultivation with irrigation. Plants produce 20–25 cm cut flower stems.

Key statistics

Virtually all *Boronia heterophylla* in Australia are currently harvested in a few short weeks.

Agronomy

Boronias can propagated from seed but viability is low. Dormancy further reduces germination and it is not readily overcome. Germination percentages are therefore usually very low, often <2% in *B. heterophylla* and *B. megastigma*, and germination may take several months. Embryo rescue *in vitro* can be used to increase the germination proportion. Seedling growth is initially slow but plants will begin to flower from one to three years from seed. Plants grown from seed will vary in most characters.

For cut flower production, boronia should be propagated from cuttings. This will provide uniformity in flower quality, stem length and harvest date. Choose a reputable nursery and allow at least four months between ordering and delivery. Tip cuttings are most successful when taken from new shoots over summer (Nov–May). High concentrations of auxins, basal heat and misting improve rooting. Losses through damping off can be reduced with good hygiene and by avoiding root damage. Boronia can be propagated *in vitro* but shoot multiplication is initially quite slow. Time for delivery will greatly depend on the availability of cultured stock material. Murashige and Skoog nutrients supplemented with benzyl amino purine (BAP at 1 μM) stimulate shoot production. Root formation can be promoted by naphthalene acetic acid (NAA at 2.5 μM) in liquid media.

Boronias require a period of cool conditions (winter nights less than 10°C) to initiate flowers. Warm conditions can lead to flower abortion at certain stages of flower development. Inadequate chilling is often seen as vegetative growth at the tips of stems and this reduces stem value. Boronias have been successfully cultivated across a range of latitudes from the hot dry conditions of Coorow, WA (30°S) to the cool temperate conditions of Tasmania (42°S) and even the South Island of New Zealand. The site should be frost free but many species are frost tolerant. Strong winds will damage shoots and weaken roots and so windy sites should be avoided or wind breaks constructed or planted.

Although some boronias naturally grow in wet areas, in cultivation they prefer well drained soils. Soils from the site

Cultivated 'Red' *Boronia heterophylla*. Non-flowering on-growth should be avoided.

should be analysed. Boronias prefer slightly acidic soils. Soils with a very high residual phosphorus level should be avoided. Sites should be tested for the presence of *Phytophthora* and nematodes. *Phytophthora* affects many Australian plants and is virtually impossible to eradicate. Also avoid sites with root attacking nematodes, such as *Meloidogyne* or *Pratylenchus*, or treat the area with a suitable soil fumigant or nematocide.

The ground should be prepared and weeds controlled before planting. Good planning at this stage is critical. Remove any large tree roots and cross rip. Remove soil from machinery before use to reduce the risk of introducing *Phytophthora* to the site. Plants should be ready to plant in winter to capitalise on the growth flush over spring/summer. Plants should be disease free, 10 cm high with well formed roots. Ensure plants are not root bound. Remove plants carefully and do not disturb the roots when planting.

Planting design will depend on your irrigation system, management practices and the species selected. Blocks of single or double rows of plants with roads for machinery access between blocks are the most common designs. Plants in single rows are 1.5 m apart with 0.7 m between plants with a spray row where required. Double rows with 1–4 m centres have 0.7 m between plants down the row and 0.5–1 m across the row. Rows are aligned north to south. In Western Australia the usual planting density of *B. heterophylla* is 7,000–10,000 plants/ha, whereas in Tasmania, densities of up to 19,500 plants/ha are used for *B. megastigma*.

A red form of *Boronia megastigma*

Irrigation or reliable rainfall throughout the year is essential for successful production. Boronias are shallow rooted and *B. heterophylla*, for example, produces a mat of roots in the top 30 cm of soil. The soil therefore needs to be kept moist. Roots are susceptible to root rot and collar rot fungi and so should be grown in free draining and not waterlogged soils. Mature boronia plants require 2–10 litres of water/day depending on conditions. Micro-irrigation supplied several times a day is preferable.

Mulching is highly recommended due to its beneficial effects on water use, and disease and weed control. Artificial mulches include plastic mulch, weed mat and local by-products such as wood chips can be used for organic mulches. Organic mulches can substantially reduce water loss from evaporation. They also keep the roots cool which reduces plant losses from water stress and slows the growth of root rots. Composted straw and other organic mulches give some control of diseases, such as *Phytophthora*, by encouraging organisms antagonistic to these pathogens.

Mulching generally gives good weed control. This is particularly important in boronia as root disturbance often leads to plant death. Grasses can be controlled with systemic herbicides like Fusilade®. Broad-leaved weeds are more difficult but may be controlled with a hooded wand using a non-selective herbicide. There are no selective broad-leaved weed herbicides registered for use on boronias.

Boronias require fertiliser application, especially nitrogen. For spring flowering species, vegetative growth occurs from mid-spring to autumn with a peak over summer. Stem length is critical for profitable cut flower growing, and fertilising during the growth phase is essential. However late application of fertiliser, particularly nitrogen, can reduce flowering especially of shoot tips, and should be avoided. Fertiliser can be applied as a solid or in liquid form through fertigation. Greater control of fertiliser application is possible with fertigation and split applications are recommended for solid fertiliser to avoid plant death or nutrient loss through leaching by heavy rain. The NPK requirement will vary depending on soil type but applications of N:P:K::90:10:130 kg/ha/year have been used for *B. heterophylla* in Western Australia and N:P:K::50:79:100 kg/ha/year for *B. megastigma* in Tasmania. Trace elements should be applied in areas deficient in micronutrients. Plants should be analysed to determine any nutrient deficiencies.

Pests and diseases

A number of pests attack cultivated boronias including nematodes, black beetle, stem borers, grasshoppers, Rutherglen bug, scale and psyllids. Nematodes and black beetle are best controlled by a pre-plant insecticide. Even insects which do not cause damage to flowers are a major problem in export shipments and will lead to rejection in most importing countries. A single insect is too many! Therefore field control of insects is essential. Depending on export requirements, cut flowers may still have to be treated for pests and diseases with disinfestation using products such as Insectigas® and Pestigas® and you should consult your exporter.

Boronias are susceptible to root diseases, especially *Phytophthora* and *Pythium*. Boronia often suddenly die and this is probably due to infection from these pathogens after wounding from insects, wind damage or water stress. Fosject® can be used to control both *Phytophthora* and *Pythium*. Rust (*Puccinia boroniae*) causes brown pustular growths on boronia and may cause leaf drop. Tilt®, Mancozeb® and Baycor® have been used but contact your local agronomist for suitable methods of control. Boronias are also susceptible to *Botrytis* and require fortnightly treatment from bud initiation to harvest, especially during wet conditions. It is better to use a rotation of fungicides, such as Rovral®, Bravo® and Octave®.

Harvest, handling and postharvest treatments

Boronia heterophylla propagated from cuttings or tissue culture will flower 12–15 months after planting but because the plants are small, this initial harvest will only yield 8–12 stems/plant. By the second year 20–30 stems can be harvested, then 30–60 stems annually. Commercial plant life is usually 5–6 years. Immature floral buds do not open after harvest and so stems are harvested when most flowers are at least partially open. Practices vary, but most boronias are pruned to a height of 25–35 cm at harvest with some horizontal laterals left intact. One-year-old plants can be pruned harder.

Key messages

- Choose your site carefully.
- Talk with your exporter.
- Know the demand for your product before you plant.

Stems should have abundant flowers for most of their length. At least 50% of flowers need to be open at harvest. Clean straight stems of *B. heterophylla* 60–70 cm, with 50–70% of blooms open and no wilting are regarded as first grade cut flowers by the Floral Export Council of Australia. Second grade stems are less than 60 cm but should have a minimum length of 50 cm, 50–70% of flowers open, no wilting and clean stems with no more than

'Lutea' a yellow flowered *B. megastigma*

5% curve. A premium is paid for >80 cm stems. Stems are bunched in fives or tens for Japan, while most other markets require the product to be sold by weight.

Without treatment, vase life is short. Standard postharvest care, including placement in clean water, removing field heat as soon as possible and storage at 1–5°C, greatly improves quality and longevity. Delays in cooling greatly reduce flower quality. Pulsing with a biocide, such as 8-hydroxyquinoline citrate (HQC, 800 mg/L) overnight (8 hours) increases vase life. Flowers are usually provided bunched to the exporter, who handles packaging and consignment to domestic and export markets. Check requirements for handling with your exporter.

Economics of production

Returns to growers are dependent on stem length, branching and flower number, straightness of stems, uniformity of stems within bunches and postharvest handling including pulsing, cool storage, disinfestation treatment and packaging. Eastern States growers usually disinfest product, pack it in cartons they purchase and deliver it to the exporter. In the west, exporters may pay for the domestic transport of bulk packed material which they disinfest and pack in their cartons.

Harvest date will also affect value and whether part or the whole crop is given the same price. For example Victorian 'Red' *B. heterophylla* is usually harvested before Western Australian product, and the variety 'Lipstick' is earlier still. Product which appears on the market earlier usually obtains a better price. Prices will also depend on the air freight charged to the exporter and this is considerably higher out of Western Australia than from the eastern States. For example freight charges to Japan in 1996 were $1.40/kg from the east coast and $2.80/kg from Perth or $0.75–$1.20/bunch higher from the west coast. The responsibility for risk will also affect prices. This includes quality claims against the product and quarantine claims; on the west coast these are the exporter's risk. A summary of prices paid by exporters to growers is presented for 1996. Be sure to check with your exporter on which charges and costs are the grower's and which are the exporter's as this will greatly affect your returns.

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Table 1. Value of ten-stem bunches of boronia produced on the east and west coasts of Australia in 1996. Returns to growers vary depending on date of harvest, quality, postharvest treatment, packaging and domestic and export freight charges. These values were kindly supplied by Collina Exports, Sunglow Flowers, Floratrade, Westralian Flora Exports and Total Flower Exports. (NA=not available)

Product	East coast	West coast
***B. heterophylla* ' Red'**		
50 cm	–	$1.50–2.00
60–70 cm	$5.00–7.00	$1.80–3.00
>80 cm	$6.00–11.00	$3.00–3.50
' Lipstick'	Premium of $1/bunch	NA
B. megastigma		
40–50 cm	$4.00–5.00	$6.00–7.00/kg
50–60 cm	NA	$8.50/kg
B. purdieana		
30 cm, 300 gm	NA	$1.20
B. clavata	$4.50–5.00	NA
B. muelleri	$4.00	NA

Note: Mention of trade names does not imply either endorsement of or preference for any product, and any omission is unintentional. Consult your local supplier for up-to-date information.

Key contacts

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Fax: (08) 9841 2707

Exporters

Collina Exports
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Fax: (03) 9329 3366

Total Flower Exports
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Fax: (08) 9351 8019

Sunglow Flowers
Phone: (08) 9525 1800
Fax: (08) 9351 8019

Westralian Flora Exports
Phone: (08) 9250 2431

Floratrade
Phone: (03) 9338 0444

Eucalypts

Cut flowers and foliage

Margaret Sedgley

Introduction

Eucalypt foliage has been cultivated for many years in southern France, Italy and the USA. The market is based upon the attractive juvenile growth of species with round or oval waxy leaves which have a silvery sheen. Once the tree attains the adult state, the foliage assumes the green, elongated leaf form and its value for foliage stems falls. Recently, however, a market has developed for adult material which has reached the flowering stage. The buds, open flowers and gumnuts of a number of eucalypt species have become the basis of a cut floral stem trade.

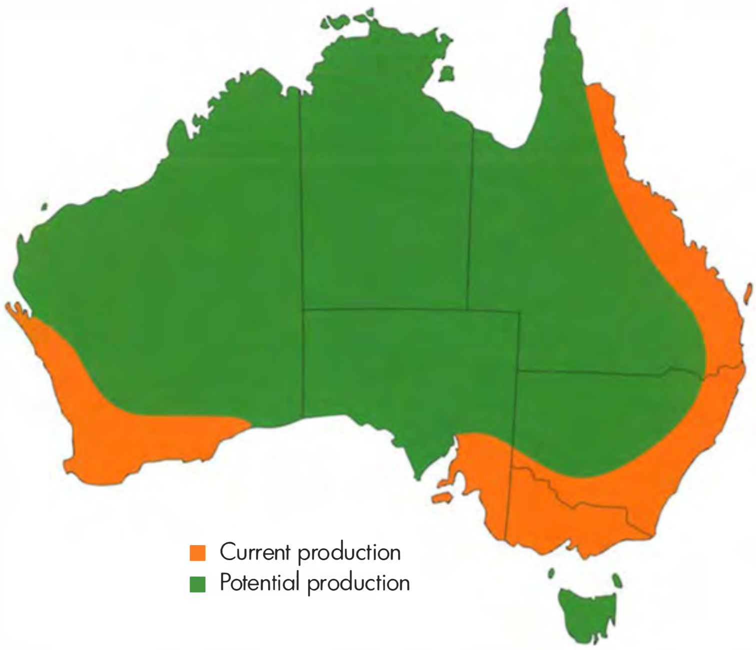
With over 500 species, the genus has wide adaptation to temperate, subtropical and tropical climates. Eucalypts are tolerant of most soil types and have a range of uses. In addition to cut flowers and foliage, they are used for amenity horticulture, timber, pulpwood, fuelwood, shelter belts, soil amelioration, honey production and water-table lowering.

The main constraint to industry development is lack of cohesion in the cut flower and foliage industry, and reluctance to communicate and co-operate. A further constraint is the lack of superior cultivars in Australia, which results in lack of uniformity in yield and quality of product. Export of fresh cut flowers and foliage is the area with most potential for expansion.

The most important personal skill requirement for the eucalypt flower and foliage industry, is recognition of the intensive nature of production. Plant care is essential for quality production and hence for success.

Markets and marketing issues

Stems are sold on both domestic and export markets. High quality and long stem length are important for the lucrative export market, and Australian exporters deal directly with Japanese importers. Stems are packed into florist size boxes for direct sales and through the auction system. Further niche markets for Australian product have been identified in other Asian countries, Europe, USA and Canada. Buds and foliage are handled through these channels.



The best period for sending product to Japan is from October to April when supply from northern hemisphere countries is in short supply. Common names have been developed for some of the species to aid in market identification.

Production requirements

Most current production is in coastal areas (see map). Of the 500 plus species of *Eucalyptus*, there are some adapted to all climates such that production is potentially possible throughout Australia. Frost tolerance also varies widely. Most species require a minimum of 200 mm rainfall per year, and many growers supply drip irrigation to ensure reliable production levels. Regular watering is especially important during spring and summer.

Soil type, salinity and pH tolerance vary widely across the genus, with species adapted to most areas across Australia.

Varieties

The main species grown for foliage production are *E. gunnii*, *E. pulverulenta* and *E. cinerea*. Many others have potential for foliage production, including *E. albida*, *E. bridgesiana*, *E. cordata*, *E. crenulata*, *E. crucis*, *E. gillii*, *E. globulus*, *E. kruseana*, *E. perriniana* and *E. tetragona*. Species for bud and flower production include *E. caesia*, *E. crucis*, *E. erythrocorys*, *E. forrestiana*, *E. leptophylla*, *E. lesouefii*, *E. pyriformis*, *E. stoatei*, *E. tetragona*, *E. uncinata*, *E. yalatensis* and *E. youngiana*. Further work is needed to determine the best species for cultivation in different areas, and not all have been fully tested in the marketplace. There are no superior eucalypt varieties for flower or foliage production available in Australia.

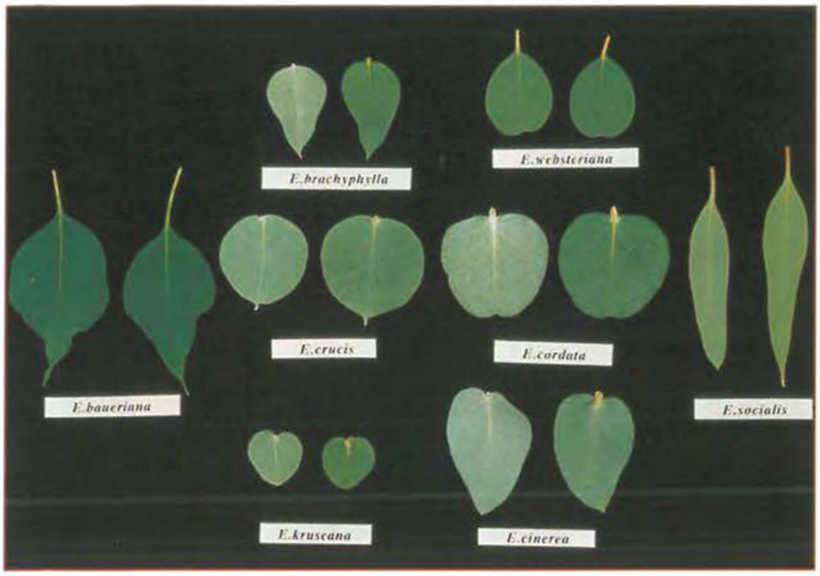
Eucalypt foliage and buds in Cologne (Germany) Flower Market

Key statistics

- Total area of cut flowers in Australia in 1992/93 was 10,114 ha.
- Largest producer of cut flowers in Australia is WA (1269 ha in 1992–93)
- Australian exports of native fresh flowers were worth over $15 million in 1995
- Australian exports of fresh foliage were worth $541,000 in 1995
- Australia has 8% of the Japanese market share
- Largest consumers of cut flowers are Europe, Japan and the USA

Agronomy

Plantings are established using seedling material, although vegetative propagation via rooted cuttings and grafting is possible for some species. Seedlings are planted out when they are 30 cm high. Planting is done in spring or autumn, and the land should be deep ripped to 30–50 cm a few months before planting when the soil is moist and friable. Spacing varies from 1.5 to 3 m within and between rows, depending on plant size and end use. Wide spacing avoids reduction of flower initiation for floral stems, whereas 30 cm within-row spacings are sometimes used for intensive foliage production. Some growers use mounded beds to increase aeration of the root zone, drainage and salt leaching, or contour banks to avoid erosion on slopes. Weed mat can be used, and black plastic also increases root-zone temperature. Tree guards are advisable in areas where rabbits are a problem. Dolomite or lime improves establishment in acid soils, and sulphur serves the same purpose in alkaline soils.



Variation in leaf size, shape and tone amongst foliage species

Fertiliser is often applied via the irrigation system, although top dressing is advisable on sandy soils to avoid leaching. In frost-prone areas, nitrogen should be avoided after mid summer, as the new growth may burn before it hardens off. Eucalypts benefit from regular applications of complete fertiliser, including trace elements, and this can be applied via organic or inorganic preparations. Nutrient deficiencies are common if harvesting is regular and fertiliser application is inadequate: common symptoms include chlorosis, leaf spot and purpling.

Pruning is essential for optimum production, but differs depending on the end use of the crop. For foliage production, the tree must be heavily pruned to maintain juvenile leaves and encourage long stem length. At 18 months of age, the main stem is pruned to one metre and major lateral branches are removed flush with the trunk. Stems for harvest derive from buds under the bark of the trunk on of the basal swelling or lignotuber. In temperate climates, pruning in late winter stimulates stems for harvest in late summer, and trees are pruned annually. More flexibility is possible in frost free and tropical climates, where irrigation can be used to control production and vary harvest time. High foliage yields are produced by *E. globulus* and *E. bridgesiana*. Average yields for most species are 10 bunches per tree, of 10–12 stems 65–70 cm in length, at 3 years of age.

For bud, flower or gumnut production, the plant must attain the adult state, so pruning is less severe. The tree should be pruned before one year old to stimulate branching and create maximum shoots for flower initiation. At harvest, some leaves should be left below the cut to provide further branches for flower production.

Pest and disease control

A wide range of insect pests attacks eucalypts, including sawfly larvae (*Perga*), leaf miners (*Perthida, Phylacteophaga*), sucking insects (*Creiis, Eriococcus,* Cercopidae) borers (Cerambycid*ae, Phoracantha*), gall forming insects (*Apiomorphinae, Strongylorrhinus*), mites, caterpillars (*Uraba, Mnesampela, Doratifera, Oenochroma*), beetles (*Catasarcus, Liparetrus,* Chrysomelidae, *Paropsis*) and grasshoppers. The leaf-eating beetle *Paropsis* can quickly defoliate plants. Pests can be controlled with a range of standard insecticides.

The most devastating disease of eucalypts is *Phytophthora cinnamomi*, which causes root rot. Care must be taken to avoid introduction of the disease, as eradication is impossible. If a property is infected, then

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Stem of *E. brachyphylla*

Stem of *E. cinerea*

Stem of *E. gunnii*

tolerant species should be grown, such as *E. cinerea*, *E. cordata*, *E. crenulata*, *E. globulus*, *E. gunnii*, *E. perriniana* and *E. pulverulenta*. *Phytophthora*-sensitive species, such as *E. caesia*, *E. crucis*, *E. erythrocorys*, *E. forrestiana*, *E. kruseana* and *E. tetragona*, should be avoided.

Leaf spot and shoot blight fungi can cause problems in eucalypt plantings, particularly in humid climates. Fungi involved include *Phoma*, *Microsphaeropsis*, *Mycosphaerella*, *Colletotrichum*, *Botrytis*, *Stemphylium* and *Alternaria*. They can be controlled using standard fungicides.

Harvest, handling and postharvest treatments

Stems should be harvested into water during the coolest part of the day, and recut under water. The leaves are carefully stripped from the basal 15 cm of the stem. Stems may be dipped into anti-transpirants to reduce water loss. Holding solutions of 2% sucrose with germicide are beneficial in extending vase life, but pulsing has no effect. Stems have a vase life of 2 weeks when kept in holding solution, or 1 week following dry transport. Stems should be dry before packing, and box liners are often used.

Eucalyptus foliage is sometimes preserved using glycerine. This gives an attractive sheen and supple texture. One part of glycerine is mixed with two parts of water, and stems will take up the mixture over a period of up to a week, or they can be immersed in a more concentrated solution. Dyes can be used to colour the foliage. The stems are then hung to dry.

Stems for export must be free of pests. Stems with gumnuts are generally sold on the domestic market as seed feeders are difficult to eradicate.

Key messages

- Natives exported to Asia, Europe and USA
- Japanese market is undersupplied
- Wide climate and soil tolerance
- Peak industry body is AF&PGA
- Supply northern hemisphere off season

Economics of production and processing

Economic analyses for new crops should be treated with caution, especially as so many eucalypt growers produce other crops as well. For a foliage farm in South Australia, producing more than 500,000 blooms per year and receiving a price per stem of $0.25, the gross farm income in 1995 was $137, 213 for average yields and $151,073 for above average yields. This represents a farm profit of $31,261 for average yields and $45,121 for above average yields, with a return on capital of 6.6% and 9.5%, respectively.

Annual expenses per ha are estimated at $300 for plants, $150 weedicides, $750 pesticides, $100 power, $100 water, $160 fertiliser, $3000 labour, $1650 machinery hire, $250 fuel, $7500 harvesting costs and $3000 pruning. First grade blooms will return $0.25 per stem, second grade $0.10 and third grade $0.05. Overall annual expenses are of the order of $16,960 per ha, against income of $19,800, with a gross margin of $2,840 per ha.

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Flannel flowers

Lotte von Richter

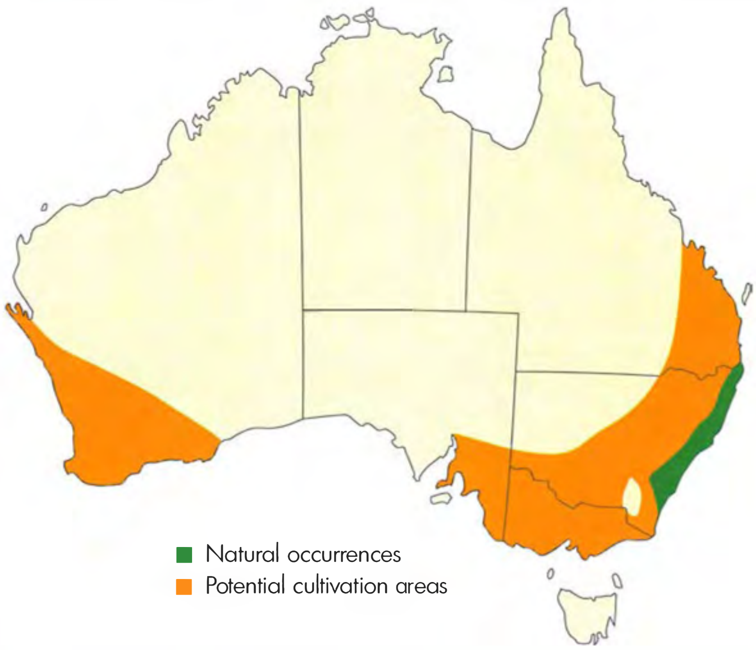
Catherine Offord

Introduction

Flannel flowers (*Actinotus helianthi*) are an emerging cut flower crop, one in a range of under-utilised Australian plants that are beginning to be cultivated for the export market. The majority of flannel flowers currently sold as cut flowers are bush-harvested but the quality and quantity available varies from year to year. Natural stands of flannel flowers are becoming fewer, mainly through urban encroachment, and ultimately bush harvesting is not a sustainable practice. Recent developments in the cultivation of this plant aim at raising its profile as a reliable, uniform and low input crop.

Despite the infancy of commercial development of the flannel flower, indications are that use of cut flower selections, good cultivation practice and identification of appropriate markets will lead to its establishment as a staple of the focal filler cut flower market. Comparable Australian natives in this market segment are Geraldton wax (*Chamelaucium uncinatum*) and riceflower (*Ozothamnus diosmifolius*). Additionally, there is a range of short stemmed, bushy flannel flower selections that have potential for the pot plant or bedding market.

Currently, flannel flowers are commercially produced in NSW, the region of origin, primarily along the eastern coast. The main constraints to production appear to be varietal availability, the need for good soil drainage, and lack of knowledge of nutritional requirements and postharvest treatment. Continuing work by researchers at Mount Annan Botanic Garden, in conjunction with growers around Australia, aims at identifying production regimes and establishing the flannel flower as a crop for the new century. As with other emerging crops, production and marketing may take some years to reach equilibrium, and there may be periods of under and over supply. We therefore recommend flannel flowers as a complementary crop for cut flower growers, rather than an alternative to other focal fillers. Flannel flower production requirements are similar to other short-lived Australian shrub and require the level of expertise expected for Geraldton wax or riceflower production.



Key statistics

Production is limited to NSW with small establishments starting in Queensland in recent years.

Exports for 1996:

- 23,000 stems from cultivated plants
- 1.1 million stems from bush-harvested plants
- proportion of cultivated stems is increasing

(Figures collated from four major export companies in both NSW and Victoria. No significant exports have been made from Queensland.)

Domestic market 1996

>5000 stems

Actinotus helianthi cultivated in Moruya, NSW

Markets and marketing issues

The popularity of Australian plants in export markets is one of the strongest assets of new products like flannel flower. Flannel flower has a traditional and ever-popular daisy-like appearance, with attractive silver-grey foliage whose interesting texture gives the plant tactile as well as visual appeal. Although the colour is currently limited to white or cream, pink occurs in a closely related species and may be added as the result of future breeding programs. The production season in NSW is August to February with the greatest production and highest returns in October, and although this is peak time for Australian flower exports from Australia, it fits with marketing and exporting efforts and can 'piggy-back' with other products.

The principal current market for flannel flower is Japan, and it is exported under similar conditions to other emergent Australian cut flowers e.g. Christmas bells. With adequate transportation to airports, flowers can reach Japan in 24–36 hours. Interest is strong but will waver if flannel flowers are perceived to be unreliable because of poor product leaving the farm gate (whether it is cultivated or bush-harvested), or if transportation and cool chain links are interrupted at any point. It is imperative therefore, that these issues are addressed before expanding into other markets. Other Asian markets have shown interest, in addition to Europe, Canada and the west coast of the USA. These markets need to be carefully explored in the coming years.

It is difficult to get an accurate picture of the export profile of flannel flowers, but we estimate that in 1996 over one million stems of flannel flowers were exported from NSW and Victoria. Of these, approximately 2% were from a cultivated source, which was probably double the previous years proportion. These figures should be treated with caution as it is only a few years since exports of flannel flowers began and accurate information is difficult to collect. With these figures in mind, however, and with Geraldton wax exports totalling in the vicinity of 5–6 million stems per year and many millions grown overseas, the export potential for flannel flower may be in the vicinity of several millions.

Best prices are attracted by long-stemmed flannel flowers (> 80 cm) with some prices as high as $A1.25/stem. The average return to the grower was $A0.47/stem. This is the average price for all stem lengths sold by one exporter of cultivated flannel flowers.

About the authors

Lotte von Richter (MScAgr) works on development of the flannel flower as a cut flower crop (RIRDC grant) at Mount Annan Botanic Garden. Lotte has worked in the private and government horticulture sectors and has recently completed a postgraduate study on native plants of Eastern Australia as bedding plants. For address see *Key contacts*.

Catherine Offord (MScAgr) is the Horticultural Research Officer at Mount Annan Botanic Garden, and previously taught horticulture at the University of Sydney. Her current work includes development of various Australian plants for horticulture and conservation of endangered species such as the Wollemi Pine. For address see *Key contacts*.

Around 5000 stems (500 bunches) were sold domestically during the 1996–1997 flowering season through Sydney's Flemington market. Small numbers were also sold through Melbourne and Brisbane markets. Many blooms are sold directly to local florists, so the true figure may be much higher. This segment may increase with development of cultivars and appropriate marketing. Prices on the domestic market are $A4.00–5.00/bunch.

Bush harvesting is the major threat to the development of flannel flower markets. Although bush-harvested flowers are exported, the perception of them is poor and makes high prices for quality product difficult to achieve. The issuing of permits under the *NSW National Parks and Wildlife Act* (1974) is slowly being restricted and availability of bush-picked product may fall considerably in future. This, and the export markets expectation of quality, are good reasons to develop economical systems for cultivation of this species.

Production requirements

Flannel flowers are considered a low input species; that is, given excellent soil drainage, low available phosphorus and adequate water, the needs of this species are comparable to other low input Australian native species. A major emerging requirement is the need for varietal development and associated agronomic optimisation. Proximity to appropriate transport and cool storage facilities is essential for premium product.

Flannel flowers (*A. helianthi*) grow naturally on sandstone areas along the NSW coast from Tura Beach in the south (36˚52'S; 149˚56'E) to south-eastern Queensland in the north. The species also occurs in isolated pockets inland from the Blue Mountains to the Pilliga Scrub region (30˚47'S; 149˚01'E) and in Queensland around the Carnarvon Gorge (24˚45'S; 147˚30'E). The climate in these regions varies considerably from high rainfall on the coast to low precipitation further inland (see Table 1). The number and severity of frosts varies across these areas, and humidity ranges from high to low.

The common feature of the areas in Table 1 is that they have the well-drained, sandstone derived soils of poor fertility and low pH (4.7–4.8) preferred by flannel flowers. Flannel flowers are abundant in seasons after good rain, and when a bushfire has swept through the area within the last couple of years. These conditions do not always prevail, and therefore flannel flower production from bush stands is extremely unreliable and not a firm basis for an industry. Growth behaviour in the wild has, however, been useful in

Actinotus helianthi flowers vary in size between 3 and 14 cm

identifying the production needs of cultivated flannel flowers.

Cultivated production areas have so far been limited to areas of natural occurrence, mainly on the coast of NSW. Although most are grown in light or sandy soils, they appear to tolerate heavier soils with a higher clay content, especially where the beds are raised and drainage is almost perfect. During hotter weather flannel flowers respond well to drip or trickle irrigation, but not overhead watering as this tends to lead to fungal problems. Areas with adequate rainfall in the summer months may not require irrigation, although low production and losses could be expected during prolonged drought. Over the next few years, the cultivation range for flannel flowers, which is probably limited only by soil type, will be extended to different regions of Australia.

Varieties

There are no named varieties of flannel flowers currently available although a number are being tested and should be available over the next few years. Prospective growers must ensure that the source of their stock material is suitable for cut flower production; that is, is the long-stemmed form and not short stature forms found growing on some coastal headlands.

Most stock material available is grown from seed, although a number of nurseries are beginning to vegetatively produce flannel flowers by cuttings and tissue culture. These latter propagation techniques need to be adopted to ensure availability of proven varieties in the future. Another possibility that should be explored is the development of seed lines for low cost production of stock. Seed germination of flannel flowers is notoriously variable. Our recent studies have shown that, while techniques such as ageing for several months and chemical or smoke treatments can be used to improve seed germination, the main factor in seed germination is the genotype and/or environmental conditions of the seed when developing.

Agronomy

Site preparation is similar to other Australian native plants; that is, soil is cultivated and generally raised into beds 1 m wide and 20–30 cm high. Weed matting and mulching with sawdust or straw can control weeds and maintain soil moisture. Irrigation should be drip or trickle and is necessary in most areas, particularly during dry and/or hot periods.

Flannel flowers are best planted out into the field while still small, approximately 3–5 cm high. Root systems are easily damaged and so avoid unnecessary disturbance

Table 1. Climate summary for areas where flannel flowers occur naturally.

	Rainfall yearly average (mm)	January temperature range (° C)	July temperature range (° C)	Elevation (m)
Sydney	1226	18.5–25.8	7.9–16.1	42
Katoomba	1421	12.7–22.9	2.4–9.1	1030
Coffs Harbour	1731	19.3–26.6	7.2–18.6	5
Narrabri	657	19.1–33.4	3.5–17.6	212
Bega	877	14.3–26.8	1.0–16.5	11

at all stages including planting out. Planting in spring or autumn is best for active growth, although summer planting may be satisfactory if the plants are irrigated. For maximum production per unit area, plants should be planted in two rows with 30 cm between rows and plants. This spacing also provides maximum interplant support against wind, which may easily blow over this shallow rooted species. Flannel flowers are considered a short-lived perennial and should be treated as a biennial. Under some circumstances, flannel flowers may be productive into their third and fourth years, but rarely beyond.

While still young, the growing shoot of flannel flowers should be pinched out to encourage low branching in the plant and thus increase flower yield . This pinching (or pruning in older plants) should be carried out in autumn, but it should be noted that if this operation is carried out too late then stem length will be reduced in the following spring.

Although from areas of low natural fertility, in cultivation, flannel flowers respond well to added fertiliser. Trials using slow-release fertilisers in pot plants (Nutricote® Total N13:P5.7:K10.8 and N18:P2.6:K6.6) indicate that increased stem number and earlier flowering are achieved at higher nutrient levels (5–10 kg/ m^3 potting media). Low to medium levels of available phosphorus (0–82.5 mg/kg) can be tolerated by flannel flowers and toxicities have only been seen at very high levels (290 mg/kg found at one grower site)

Pest and disease control

Relatively few pests are attracted to flannel flowers and consequently little chemical control is necessary. Mealy bugs may cause problems during active growth periods (spring and autumn), living in and sucking on the vegetative and floral tissues causing distortion and stunting of new growth. Because these insects are usually covert, feeding inside the tissues, a systemic rather than a contact insecticide spray is more useful e.g. Folimat® (active ingredient 2 g/kg^{-1} Omethoate).

Root rots are the most damaging diseases affecting flannel flowers, and the most difficult to control. Fusarium wilt and collar rot, caused by *Fusarium oxysporum* and *F. solani*, result in plants dying within a week and no control is available. During the propagation of flannel flowers, grey mould caused by *Botrytis* sp. is common and may be controlled by reducing humidity (we use intermittent mist instead of fog for cuttings), avoiding overcrowding, regular removal of dead material and keeping temperatures in the range 20–25°C.

Left: stems of cultivated flannel flower plants grow to 1 m in length.

Right: flannel flowers growing at Mount Annan Botanic Garden

Harvest, handling and postharvest treatments

Flannel flowers will produce saleable blooms in the first spring season if planted by at least the mid summer of the previous year (approximately 8 months); they may produce a second crop in late summer although stems lengths will be reduced. Yields for this crop have not yet been established but it is estimated that production will be higher in the second flowering season.

Flowering heads are ready for harvest when approximately 15–20 individual florets are open in the centre of the disc of the main flowering head. Harvesting should be done in the morning and the stems placed directly into cool water. Stems should be cut as long as possible but never cut into the oldest part of the stem as this may kill the plant. Blooms can be stored in a cool room (4°C), standing in water, for several weeks although maximum vase life is achieved if they are transported (in water) immediately or overnight. The use of chemical treatments such as sucrose, citric acid and bleach may assist in prolonging vase life and controlling fungal diseases. Further work is required on postharvest treatments to maximise shelf life.

Key messages

- a low input crop
- emerging export potential
- complements other Australian wildflower crops
- a key focal filler

Table 2. Gross margin analysis for production of one hectare of flannel flowers.

Flannel flower gross margin analysis		Supporting information		
Summary	$/stem	Prices	stem grade (cm)	40–50[f]
Gross sale price	0.89[a]		Yen/$AUD	90
Sales & freight costs	–0.46[a]		stems/box	160
Packaging	–0.03	Yields	year 1	8[g]
Processing	–0.10[b]		year 2	30[g]
Harvesting	–0.06[b]		plant life, years	2[g]
Growing costs	–0.08[b,c]		plant loss	25%[c,g]
Plant cost	–0.07[d]	Costs	plant	$2.00[h]
Gross margin/stem	0.09		plant loss	$0.67
stems/plant	19[e]		package	$4.86
stems/ha	330,671			
Gross margin/ha	$32,488	Site	area	1 ha
			plants /ha	23,205[i]

[a] Japanese auction market '96; data from IHM P/L
[b] based on average for riceflower growers; IHM P/L
[c] Growing and loss costs may reduce with increasing experience and research
[d] Amortised plant cost may reduce with self-seeding in subsequent crops.
[e] Saleable stems, averaged. over 2 year crop
[f] 40–50% of production may be longer stems; may increase prices up to 50%.
[g] Mountain Nursery '94–'96
[h] Plant cost may reduce with propagation R&D; plants in limited supply
[i] Gross margin/ha is sensitive to plant density; optimum density may decrease with better varietal selection; but this may improve yield.

Flannel flowers are graded according to stem length: 40 cm is the shortest marketable length; the export markets prefer stems 60–80 cm and longer if available. Stems are bundled in groups of 10 and placed in cartons containing, depending on length, up to 200 stems. More stems can be put in a box using bunches of different stem length but importers may have their own preference. Bunches in microperforated sleeves or wrapped white paper present well and suffer less damage during transport.

Skin irritation may arise in some people when handling flannel flowers due to the fine hairs on the stem. Due care should be taken during handling and especially harvesting, when gloves, long sleeves and a mask should be worn, especially during very dry conditions.

Economics of production

The production of flannel flowers is still in the developmental stage and some assumptions were made when compiling the gross margin analysis given in Table 2. This analysis was established from one grower for the 1996–97 season only. At this stage the flower yield has not been assessed over longer periods and plant density has not been optimised.

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Geraldton wax and relatives

John A. Considine
Digby Growns

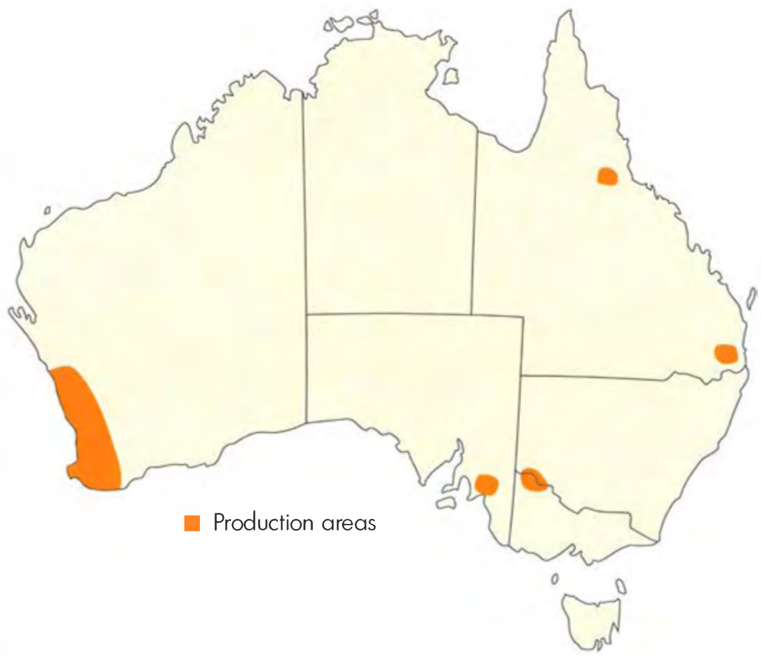
Introduction

Geraldton wax (*Chamelaucium* spp.) is Australia's leading commercial wildflower. It has reached the top 20 plant species in terms of volume sold in Europe, and is on the brink of achieving 'commodity' status in the international cut and potted flower market. Geraldton wax has achieved this status because of its productivity, vase life, and suitability as a feature-filler flower in arrangements and posies. However, Australian exports of Geraldton wax are less than 10% of world total production, and world production of floricultural plants of Australian origin constitutes only about 1% of world production of all floricultural products. The challenge for the Australian industry is to capture market share.

The major producer of Geraldton wax is Israel (about 80 million stems/year) which sells into Europe principally, but increasingly into other markets including Japan. Production has been reported to be increasing in California, Mexico and South Africa, while Peruvian material was prominent in the market during June and July 1997.

The key strength of the Australian industry is its location as a southern hemisphere producer in the emerging Asian economic trading zone. This is an advantage for producers of perishable and seasonal products like Geraldton wax because perishability combined with location give a near exclusive market window into this zone. As the holder of the bulk of the genetic resource Australia is also best placed to develop new varieties as the market matures and consumer demands become more sophisticated.

A weakness is that the export floricultural industry is small by world standards and lacks significant product diversity (it is perhaps too focused on native plants). The industry has no national strategy for marketing and competing in a global marketplace and commits few resources to capitalising on our capacity for research and development. Our market access costs are still too high by international benchmarks. While some significant restructuring is occurring in the market chain to Japan, the industry will need to continue to address this issue if it is to double sales by 2002. Additionally, and importantly, our on-farm processing and local off-farm costs are also too high by international standards and few would be profitable at the F.O.B. values achieved by Israel (Fig. 1).



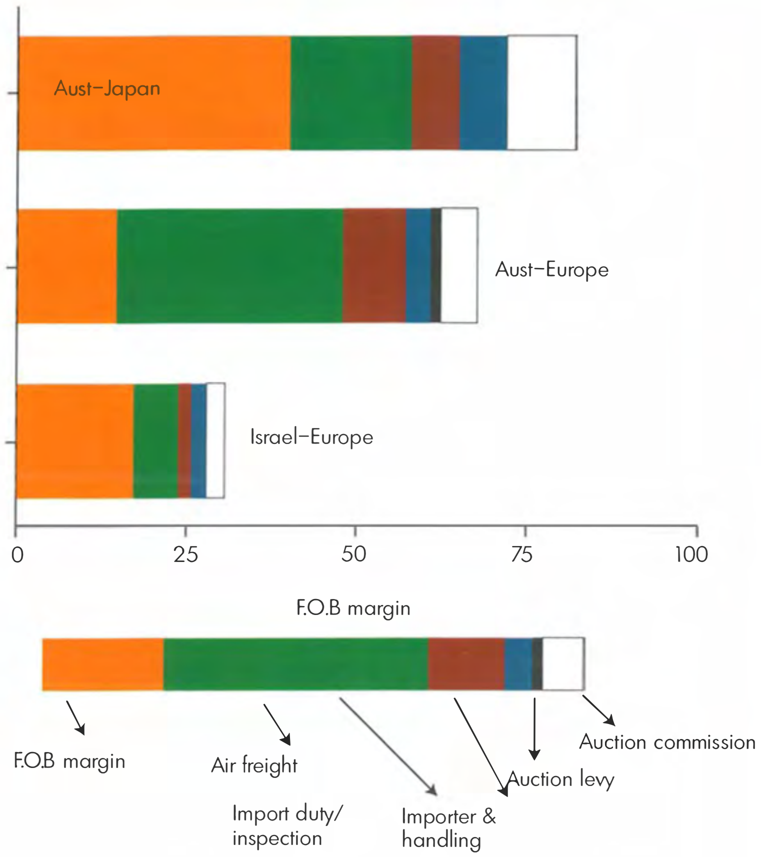


Fig. 1. Some values from the European market in 1991 representing the challenges faced by Australian growers in becoming internationally competitive. Freight is the single largest challenge and this is affected significantly by scale and integration but while the F.O.B. margin seems attractive for the Japanese market (65¥ @ 80¥/$A), about 60% of that was off-farm costs.

Key statistics

Geraldton wax production

	Qld	WA	SA	Vic.
Growers	50	100	12	10
Bunches	1,000,000	1,000,000	583,000	230,000

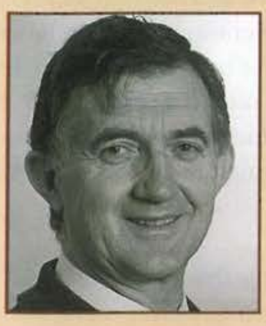
Markets and marketing issues

Australian-produced waxflower is marketed principally to Japan, the USA (Los Angeles primarily) and Europe. Local sales are growing strongly. There is increasing diversity in the way the product is marketed as the industry strives to find more economical and attractive marketing strategies. Some are experimenting with marketing of cellophane sheathed bunches directly to supermarkets. While the standard has been bunched, 800 mm stems for the Japanese markets, and 600 mm stems for the American market, in boxes of a total of between 120 and 180 stems, mini boxes (inner boxes) containing about 50 stems are becoming the market standard in Japan.

Adding value is essential while Australia remains poorly competitive in its costs of market access. This may be through new varieties, new market windows, new outlets or new ways of presenting the flower to the market.

Infrastructure for cool storage and refrigeration in the marketplace and in the home is much lower in Asia than in 'the West' and there is a greater reliance on daily purchases for fresh, perishable products. In this environment, small packages seem to make good sense. Nevertheless, 'super' and 'mega'-markets are developing in Asian countries and they have specific product requirements which may be closer to those of the American supermarket trade than the traditional Japanese auction house. Only those producers and export agents with access to long lines of uniform product will have access to this emerging direct to market trade. The small producers will be restricted to niche marketing and the auction house route, with the attendant high market access costs through the several layers of commissions and entry fees. The fixed price market is now only a small component of the total trade, but growers with a particularly attractive line may still be able to negotiate a delivery price.

About the authors



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See *Key contacts* for the author's addresses.

Achievement of international benchmarks in market access costs will require a more direct access to the market and more efficient packaging practices, such as those practised by Israeli growers. This will require larger package units, denser packaging and the development of practices to minimise heat build-up, such as assured maximum time to market guarantees and modified atmosphere packaging to reduce temperature build-up through respiration. It may also require a market re-packaging centre to break the package down to end-user-preferred specifications. Such infrastructure cannot be justified on the basis of Geraldton wax alone.

A key factor in successful marketing is understanding the legal market entry requirements, especially phytosanitary certification, which is particularly stringent in Japan. Failure to meet those standards leads to the imposition of high surcharges and a loss of product quality through extreme disinfestation treatments. Phytosanitary practices must begin in the field to ensure that harvested product has as low a level of infestation of insects and pests as possible.

Flowers display a relatively high elasticity of demand, as is demonstrated in Figure 2 (price elasticity of demand curve). More recent data can be found in RIRDC Research Paper No 97/41 (see Key references).

Waxflower began as a novelty product but has now moved to commodity status and thus can expect to gain prices no higher than those of other mainstream products such as carnations, roses, gypsophila and statice. With the maturing of the market, there will be continuing pressure to force the opportunistic grower out of the market, and only those who can be profitable while competing at this level will continue to succeed.

Key messages

- Develop marketing and business plans before investing, and discuss these with one or more marketing agents, consultants and advisers.
- Take care with site selection and even more care with choice of nurseryman and cultivars.
- Keep good records, especially of your own time.
- Manage wisely, eliminating unnecessary activities while aiming at 'best practice' in terms of product quality.
- Don't be unduly influenced by current tax rules, these are subject to change.
- Adopt the Israeli grower attitude: make financial success your primary objective.

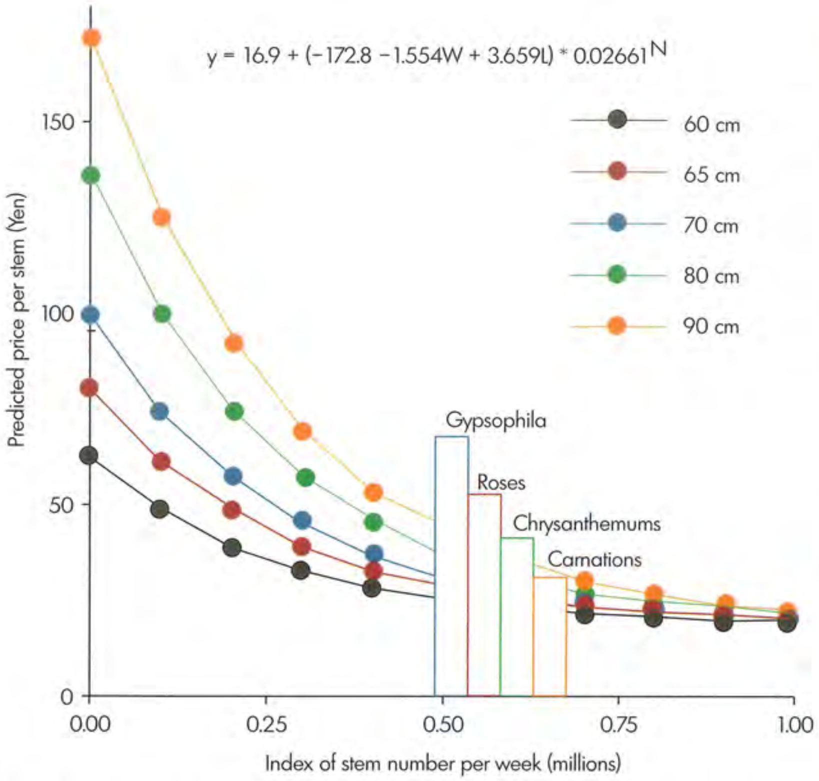

Fig. 2. Analysis of the returns from the Japanese auction market for the 1991 season, showing the price trend for Geraldton wax as volume increases and quality (stem length) declines. Note that this is not a complete sample and represents data from one supplier only. The actual stem numbers are about twice those indicated and apply only to the 1991 season. As the market expands these values will change but the trends will probably remain similar. The bar graphs show the average values for some standard products over the same period.

'Jurien Brook' is a *Chamelaucium uncinatum* selection which has small, pale pink/mauve flowers that do not fade with age. In Perth it flowers about two weeks later than 'Purple Pride' and about four weeks ahead of plants with similar attributes.

Production requirements

Chamelaucium is endemic to Western Australia and occurs naturally in the South Western Botanical Province. The genus comprises about 31 species and is a member of the *Chamelaucium* alliance, a grouping of closely related, small, floriferous woody shrubs of the family Myrtaceae, most of which occur or are endemic to south-western Australia: *Verticordia*, *Darwinia*, *Scholtzia*, *Actinodium* and the eastern Australian *Thryptomene* are potentially the most important horticulturally.

Wax flower and most of its relatives are intolerant of frost (screen temperature less than 0°C) and warm humid conditions, and are highly susceptible to grey mould (*Botrytis cinerea*). Most species in this group are susceptible to root rots such as *Phytophthora*, *Pythium* and *Fusarium:* regular spraying with a proprietary spray such as Fos-Ject will usually keep them at bay. They are well adapted to cool wet winters and hot dry summers (coastal Mediterranean type climate). They generally prefer neutral to acid soils which must be free draining. Some new selections and hybrids are showing promise of being better adapted to frost and/or alkaline soils. The plants respond well to irrigation, and economic production will depend on irrigation to at least 70% of pan evaporation. The areas that meet these requirements are indicated in a general way on the accompanying map, though local conditions will always be important in determining success.

Varieties

'Purple Pride' remains the most popular variety in Japan though white varieties predominate in Europe. Purple Pride is floriferous, productive, has little on-growth present at flowering and has a good vase life. The major white variety, 'Alba', tends to be too vigorous and produces significant on-growth unless water and fertilisers are managed carefully. It is available for only a short period of the marketing season and there remains a need to produce a series of 'Purple-Pride'-like cultivars with diverse flowering times (Israeli nurserymen have reputedly selected an autumn flowering sport). Purple flowers rarely occur in the wild and nothing is currently known about the genetics of flower colour, except that it is complex. Most naturally occurring plants bear flowers that are various shades of pink.

There are now about 50 registered cultivars in Australia and the trend is towards hybrids rather than wild-type plants such as 'Purple Pride', 'Alba', 'CWA Pink' and 'Mullering Brook'. Newly available hybrids include 'Painted Lady', 'Eric John' and 'Esperance Pearl'.

It is important to test grow plants on your property to assess their productivity, form and flowering date. These factors vary markedly from site to site, even over relatively short distances. Commercial success will depend on making sound choices at the outset. A continuing cultivar assessment program should be a part of normal practice. Production at a time when few others of a particular type of flower are available will have a marked bearing on profitability.

Small specialist growers may be able to vary the time of flowering to a degree through manipulating daylength (exclude light to shorten the day length to bring flowering forward, or use artificial light at night to delay flowering). These methods are practised to a degree in Israel but we have no practical experience in Australia. Also, some varieties respond well to plant growth regulators which can increase flower number and delay flowering.

Agronomy

Site selection and preparation are important. In regions and localities subject to radiation frosts (defined as a screen temperature of 2°C or less), care should be taken to plant on higher ground or on slopes that allow free air drainage to minimise frost risk.

Geraldton wax is subject to soil-borne pests and diseases, and if areas are to be replanted over successive seasons care should be taken either to fumigate the soil or to rest it and plant an appropriate cover crop that will not be a host to soil-borne pests and diseases. Crops that have been recommended include cereal rye, tagetes and a brassica crop. Geraldton wax, and presumably its relatives, respond well to added nitrogen and the use of a clover or sub-clover cover crop may be of benefit (though avoid types that produce burrs which may contaminate the crop). Cover crops may need to be avoided in frost-prone areas because they act to insulate the soil and increase frost risk (though with a herbaceous plant such as Geraldton wax, the use of traditional passive methods of frost control may be of minimal value). The planting of cereal rye to protect young plants over summer during the establishment phase is recommended, or at least the establishment of some form of wind protection.

A nitrogen and potassium fertiliser regime of 15 to 30 kgha is recommended, rising to 80 kg/ha in year 4. In areas that are alkaline, an iron chelate may have to be added and other nutrient deficiencies dealt with as they arise (eg. calcium, zinc and copper in Western Australia's acid sands). Geraldton wax does not appear to be intolerant of phosphorus, but neither does it respond strongly to its application. Fertilisers are best applied by fertigation.

It is vital that an intending grower coordinate with his nurseryman to ensure that plants do not become root-bound before planting. Commonly, plantations can suffer losses of as much as 1/3rd of their plants in years 3 to 4 through poor nursery practice or holding the plants before planting out.

Planting can be done at almost any time of the year provided there is a good irrigation system. The ideal time to plant is autumn and this will lead to a small production in the second year and nearly full production in the third. Vigorous cultivars such as 'Alba' and 'Purple Pride' are usually planted in single rows at 2 m spacings and a 4 m inter-row, while with less vigorous types the spacing drops to as little as 1 m between plants and 3 rows with an inter-row spacing of 4 m. It is probably best to work to a compromise standard so that irrigation infrastructure can be used for more than one crop without modification.

Good husbandry means good weed control, beginning before planting (eg. with a pre-emergent spray such as Simazine™). As the plants mature, shed leaves and shading will prevent weed growth under them. Grasses may be controlled with Fusilade™ but care should be taken especially with more generic herbicides which can severely damage waxflower. A hooded, low pressure sprayer is recommended. Sprays that have been used successfully include Oxadiazone™, Metribuzin™ or Sethoxydim™.

Pest and disease control

Pest and disease control form a part not only of the production and management system but also of harvesting and processing. Harvested material must be free of insects, spiders, snails and other minor pests that may constitute a quarantine problem. Root diseases can be a major problem, *Phytophthora* and *Fusarium* in winter, and *Pythium* in summer. These can be minimised through good hygiene and ensuring that plants are purchased from a registered nursery with a good standard of hygiene. Well-aerated and free-draining soils are an aid, as is the development or use of soils with a high organic carbon content, because these factors favour beneficial, as against pathogenic organisms. Even with good practices, most growers find it necessary to regularly apply Fos-Ject™ or equivalent to maintain plant health.

From budding onwards and especially during or following cool and wet weather conditions likely to promote the spread of *Botrytis*, growers should apply a rotating sequence of fungicides selected to control this disease (eg. Rovral™, Bravo™ and Octave™). *Alternaria* can also be a problem on leaves and is best controlled with Mancozeb™. Growers should keep in touch with agricultural chemical companies and departments of agriculture for current recommendations because of the regular changes to legislative and health requirements.

Gall wasp is a problem in certain regions, eg. Queensland, California and recently Israel. It is endemic in Western Australia but presumably is controlled by natural predators. Use of natural predators is reported to be effective in Queensland, and methods of chemical control have been of limited success.

Other insects such as thrip are a serious phytosanitary issue and must be controlled in the field with Mavrik™. Carbaryl™ can be co-applied if spring beetles are also a problem. Ambush™, a synthetic pyrethrum, or Carbaryl™ can be used to control leaf webbing larvae, while wingless grasshoppers and Rutherglen bug have been controlled with Maldison. Baiting is probably the best method of controlling wingless grasshoppers.

Harvest, handling and postharvest treatments

Most of the costs of production occur from harvesting onwards and it is important to minimise these to achieve economic efficiency. As a rule of thumb, every time a stem is handled a cost equivalent to the cost of production to harvest is added. The way in which this is managed will depend greatly on the scale of production.

'Esperance Pearl' is a hybrid between Geraldton wax (*Chamelaucium uncinatum*) and large waxflower (*C. megalopetalum*). It has brilliant white, medium-sized flowers which turn pale pink with age. In Perth it flowers two weeks ahead of 'Purple Pride'.

Current practice for a family operation is to pick into the postharvest solution (1), grade and bunch (2), cool and then dip in a pesticide and possibly a fungicide (3), drain (4), box (5) and store (6) for transport. A large commercial operation may use a different sequence depending on the processing chain, and the postharvest treatment may need to be optimised according to the destination (eg. Europe vs Japan).

Much of this is carried out under roofed conditions adding significantly to the overall capital costs. Large operations can mechanise much of this but smaller growers will need to give careful thought to the management of the overall process to minimise costs without loss of quality. Some growers bunch directly thus eliminating one step but adding to the care that needs to be given to stem selection when picking. For the smaller and new growers, the best practice may be to contract all of the postharvest operations to a contractor or marketing agent.

Some growers are now experimenting with picking dry and avoiding the cost of transporting in water or postharvest solution and improving postharvest pulsing with silver thiosulphate (STS). Our experience is that this may in some circumstances marginally reduce quality while under other circumstances it has no effect. More research is being done to assess these factors along with other harvest and postharvest issues. Flowers are normally harvested at 30% of flowers open. This is not easy to assess and those new to flower production should begin by counting flowers so as to harvest at the right stage.

Postharvest treatments include dipping in an insect and miticide (eg. Deltamethrin™ or Cislin™) plus a fungicide (Rovral or Benlate™ or Iprodione plus Mancozeb) and a wetting agent (eg. Agral 600). Flowers may also be treated with STS by allowing the flowers to stand in a solution for 15 to 30 minutes depending on conditions. This protects the flowers against ethylene. Silver is regarded as a dangerous heavy metal and is being banned in some countries. It is likely to be replaced by new treatments soon.

Economics of production and processing

The economics of production are very much an enterprise level issue, varying widely on the basis of scale of production, range of products and cost of market access. Market access costs are minimal for a road-side operation but increase to as much as five times the production cost for European and eastern seaboard USA markets. The major portion of trade is through established market channels, through local agents to freight forwarders to import agents, auctions and onto the retailer. In this long market chain 2/3rds of the auction price go to pay costs external to Australia. Some marketing agents are taking advantage of the Internet to direct market to individual florists, both here and in America, while others are marketing directly to individual florists, garages and general stores. Wholesale flower markets are being established in many countries and will establish benchmark prices and assist in establishing an integrated focus on flowers, regardless of the nation of origin of the genetic resource. This will benefit the Australian floricultural industry which must diversify to remain viable and internationally competitive.

A framework for a viable business though a detailed farm and marketing model is available from the University of Western Australia. Table 2 sets out some indicative costs.

The owner–operator partnership (e.g. family) specialising in wildflowers should aim to select a range of products (ie. crops complementary to waxflower) that will build to a unit that will be producing for 9–10 months of the year, leaving time for routine annual maintenance and relaxation. The scale should be such that the family can manage, harvest and distribute all of their production without calling on external labour. Such an operation should aim to be profitable on about 1500–2000 bunches per week throughout the production period. This will enable the capital cost to be spread over the range of commodities, give some protection against seasonal losses in a few flower types and ensure full employment of the family unit. This is a better model than aiming to produce a few lines at a large scale and then employing labour to manage the workload during harvest. The scale of production will be much larger if one chooses not to process and pack because of the labour-intensive nature of these, but the unit will forgo the price advantage available through niche marketing and direct sales to the public and to individual businesses. A 4 ha, intensive field grown flower operation could be a full-time activity for such a unit, depending on the crops selected.

Table 2. Indicative costs of production and marketing of waxflower to Japan. The data are based on an exchange rate of 80¥/$A and a price of 65¥ per stem.

Variables		
Yen per stem	65 Yen	
Stem length	80 cm	
Stems per box	180 n	
Week of season	8 n	
Length of season (weeks)	16 n	
Exchange rate	80 Yen/A$	
Commission (auction)	10.0%	
Commission (Japan. agent)	8.0%	
Clearance & distribution	1,250 Yen/box	
Air freight ($/box)	32.5 A$/box	
Commission (Aust. agent)	12.5%	
Aust. delivery & clearance	2.5 A$/box	
Other Aust charges	0.0625 A$/stem	
Boxes	3 A$/box	
Packing and treatment	0.04 A$/stem	
Picking	0.05 A$/stem	
Production	5,000 A$/ha	
Productivity	100,000 Stems/ha	
	A$	**%**
Japanese commission	0.233 A$/stem	28.7%
Airfreight	0.180 A$/stem	22.2%
Aust. commission	0.050 A$/stem	6.1%
Delivery etc	0.097 A$/stem	12.0%
Harvesting, packaging	0.107 A$/stem	13.1%
Production	0.050 A$/stem	6.2%
Gross margin	0.095 A$/stem	11.7%
	$0.81	

Source: Adapted from Considine (1996).

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Ixodia daisy

Gail E. Barth

Introduction

Ixodia daisy (*Ixodia achillaeoides* ssp. *alata*) is an Australian native flower which is known by the common names of Hills daisy, Mountain daisy, and South Australian daisy. Ixodia has been harvested from native stands for over 40 years in SA and an industry has developed in the past 10 years in cultivated Ixodia grown in South Australia, Victoria and Western Australia.

The value of the world fresh flower trade has been estimated at US$26 billion. The total value of Australian dried flower exports in 1996 was $11.6 million, with the estimated value of ixodia production being $330–520,000 in the same year. Ixodia is well placed to become a major dried flower commodity because of its appearance, durability and suitability to dying. There is interest from many overseas markets in the supply of ixodia and at this date Australia still has a marketing advantage in product availability and access to improved varieties.

A major constraint to the industry has been the export of poor quality product which has had an adverse affect on price and demand on some overseas markets. Poor quality results from the use of unselected or unsuitable varieties or from incorrect harvest and handling procedures. Several soil-borne diseases are also currently limiting production and in some cases causing severe losses to cultivated stands.

Ixodia could also be marketed as a fresh product. Flowering stems are tolerant of packing and transport conditions and vase-life is good on all major forms. Drawbacks to fresh marketing include: the temporary closure of the flower heads on contact with moisture or in conditions of high humidity, and sticky resins in the leaves and stems which leave a residue when handled.

Production requirements

Ixodia is native to high rainfall and coastal districts of South Australia and Victoria. Its natural distribution is in cool Mediterranean-type climatic conditions with cool wet winters and warm dry summers. Under cultivation, ixodia requires well-drained sites, preferring sandy to loam soils, being short-lived on heavy soils. It tolerates a wide range of soil pH but chlorosis problems increase in alkaline soils and may require soil amendment. The performance of ixodia in interior, high-temperature horticultural districts has not been adequately assessed. During periods of

extremely high temperatures, foliage burn and damage can be observed.

Flowers are initiated by cool temperatures in winter and spring, which limits production of ixodia in subtropical areas. High summer humidities also encourage a range of leaf diseases and impact on the productivity of plants.

Wind damage can be severe on exposed sites, with young plants distorted or broken at the crown. Wind protection should be established before planting, to assure high yield and long stem length. Heavy frost can damage soft shoots and flower buds in the spring, causing severe crop losses. Some varieties are more tolerant of frost and should be selected for frost-prone sites.

Varieties

Varieties are based on the origin of natural stands which range from the northern Mt Lofty Ranges near Adelaide in South Australia, to coastal districts and into the Grampians National Park, Victoria. A comprehensive study is now in progress to categorise and assess commercial varieties in use, improved varieties and new collections.

Agronomy

Ixodia is generally grown as a row crop under drip irrigation with spacings of 0.5– 0.8 m between plants. New plants are pinched, or lightly pruned up to five times in the first year to develop a low, branching, dense shrub which can support many flowering stems and resist wind damage. Under cultivation most forms are productive over a three year period with subsequent decline in vigour or harvestable stem length after this time.

About the author

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Annual nitrogen applications in the range of 75–110 kg/ha are recommended for good productivity, these applications being spilt over 3–4 applications. If soil potassium levels are less than 150 ppm, it would be advisable to also apply 50 kg/ha total K. Phosphorus would best be applied as superphosphate incorporated in the soil when a new crop is planted. Applications of 50 kg/ha would be adequate in most soils but soil testing is recommended before planting.

At harvest, only green stems should be cut, as darkened, lignified stems will not re-shoot new buds. Pruning follows harvest and is used to remove damaged material, lower the height of the bush and increase lateral branching and subsequent yield.

It is recommended that weeds be controlled with preemergent herbicide applications in spring and autumn. Glyphosate is commonly used as a knock-down spray and is best applied with a hooded or a controlled droplet applicator.

Young plants showing drip irrigation system and wind breaks

Major geographic forms of *Ixodia achillaeoides* ssp. *alata*

Origin		Bloom period	Flower size	Other characteristics
Central Mt Lofty Ranges	SA	Jan–Feb	8–10 mm	thick winged stems, tall bushes quality blooms
Lower Mt Lofty Ranges	SA	Dec	10–12 mm	
Kangaroo Is.	SA	Jan–Feb	6–8mm, >12mm	variable forms
South-East	SA	Nov	12–15 mm	high yield first year, short-lived
Yorke/Eyre Peninsula	SA	Dec–Jan	5–7 mm	potential for pot plants and landscape use, short stems
Nelson	Vic	Nov–Dec	12–15 mm	variable, sprays and flat topped, high yielding, good quality
Donovans	SA	Jan–Feb	12–15 mm	late form, similar to Nelson varieties
Portland/ Mt Richmond	Vic	Dec	>15mm	large flowers, wide leaves and thick stems. Short stem length
Grampians	Vic	Feb–Mar	5–10mm	fine stems, short stem length
Anglesey	Vic	Feb	8–10mm	pink buds, potential colour variants

Note: Within each of these categories there are varieties which can be further classified as early, mid-season or late in blooming, which allows for staggering harvest if this is desirable from a labour or marketing standpoint. Different nurseries offer selected varieties based on flowering period and flower appearance. There has been little assessment for yield and agronomic characteristics or disease tolerance.

Key statistics

- Australian exports of cut flowers in 1995–96 were worth $30.2m ($18.6m fresh; $11.6m dried)
- The largest markets for Australian dried flowers are the US, Japan and Germany

Propagation of ixodia is by herbaceous cuttings, which root easily under mist over most of the year. Cuttings are prepared from non-flowering shoots taken from vigorous plants which are not under moisture stress. Cuttings taken from plants in native stands or unirrigated plantings are best taken after a flush of growth has just hardened. IBA formulations of 1000 ppm can enhance rooting, high concentrations >3,000 ppm can damage cuttings. Ixodia can be grown from seed if variability is desirable. Seed requires smoke treatment for germination.

Pest and diseases

The most serious losses of ixodia in commercial plantings have been from the disease *Verticillium dahliae*, which can survive in infected soil from vegetable or other host crops and infect ixodia when it is planted. This fungal disease is more serious where levels of plant pathogenic nematodes are shown to be high. There are no known controls other than fumigation.

Phytophthora cinnamomi and *P. cryptogea* are also pathogens of ixodia and cause characteristic decline and yellowing of plants before death. Phytophthora root rot is the most serious disease of Australian native flower crops and should be carefully guarded against by the use of clean plant material, strict hygiene practices and attention to the previous history of the planting area. Treatment for phytophthora involves isolating infections by removing plants and drenching the site and neighbouring plants with a fungicide such as Fongarid. The remaining crop should then be treated with a spray of Foli-R-Fos, as a preventative treatment to contain its spread, and the planting area rotated with a non-susceptible crop in the next planting cycle.

Leaf diseases include powdery mildew and botrytis which are increasingly a problem in crowded plantings where overhead irrigation is used or where weeds are profuse. Sulphur sprays have been found to be particularly effective in controlling powdery mildew. Botrytis often damages the centres of open flowers, darkening them prematurely and making them unsaleable. Other diseases isolated from ixodia include alternaria leaf spot, mycoplasmas, and fusarium.

The primary insects pests of ixodia are aphids and leafrollers which both distort the growing tips and affect flower quality. Regular monitoring for the presence of these insects and swift control will prevent any significant crop damage. Native beetles are often attracted to blooming plants in large numbers and are a nuisance to harvesters but do not damage plants.

Harvest, handling and postharvest treatments

Ixodia blooms are usually harvested by hand, by snapping the stems between the thumb and forefingers. Harvesters should wear gloves as ixodia is high in sticky gums which blacken and build up on hands and tools. Harvest involves either bunching in the field (most common) or machine-assisted cutting with sorting and bunching taking place in the shed. Stem length should be a minimum of 30–40 cm for dried bunches and 40–50 cm for fresh. All bunches should be retrimmed in the shed to an even base, this being particularly important with flowers prepared for fresh marketing.

Flower maturity at harvest is an important quality consideration which is often overlooked in a product destined for dried flower markets. Flowers need to be fully open, with the centre disc flowers visible and in an early to middle stage of bloom. Flowers harvested past maturity have a raised centre and the disc flowers have changed from their bloom colour of yellow or purple to grey or brown, which affects the overall appearance of the flower head and product.

Flower bunch size for dried product is usually determined by weight, or diameter of the top of the bunches, where flat topped varieties are used (20 cm). Fresh flowers are sold by stem number, 10 or 12 stems per bunch, depending on size of the flower heads. While demand has exceeded supply, growers have been able to market bunches for dried markets in their 'green' state before drying. Flower bunches can be packed easily while they are still flexible and they travel with little damage.

Shed drying is accomplished by hanging bunches on racks (photo), good ventilation being essential to prevent botrytis damage if the air temperature is cool. Rapid drying, away from strong light assists in maintaining the green colour of the foliage and stems. If flowers are to be stored for marketing later in the year, bunches should be thoroughly dried, boxed and treated for storage pests.

Harvest from one-year-old plant, showing pruned bush (on right)

Close-up of a bunch of a large flowered variety

Rack system used for air drying ixodia bunches

Key messages

- Ixodia is a unique dried flower crop which is highly suited to European and N. American markets
- Ixodia has been successful as a fresh flower crop in Japan and there are varieties under development particularly suited for fresh markets
- The peak industry body is the Australian Flora and Protea Growers Association

Flowers to be marketed as a fresh product should be rehydrated after harvest in clean water for several hours or overnight in a cool shed or cool room. Flowers of some varieties can be stored for up to two weeks in a cool room and still have a vase-life of two weeks. Storage in water can induce premature stem blackening in some varieties, and high humidity increases botrytis. It is essential that any variety destined for fresh markets be assessed for postharvest life and tolerance of transport. Ixodia flowers close in high humidity, so buyers in export markets need to be aware that the appearance of boxed or sleeved bunches is inferior to the open flowers. Flowers reopen as soon as they dry.

Economics of production

Plantings of 1–5 ha are a viable size for a family flower farm, with outside labour employed for harvest. Early large-scale attempts at production of ixodia did not succeed because of difficulties in harvesting large amounts of flowers over a short blooming period, poor quality control and poor varietal selection.

The following figures from an enterprise analysis are provided as a guide only and assume high yielding, uniform varieties and good market access. These figures are for a three year production cycle, assuming no yield in the first cropping year. Preparation, planting, irrigation and windbreaks for a 1 ha planting based on 12,000 plants is $15,600. Annual production costs/consumables at $1,500, overheads at $8,600 and harvest and marketing costs at $5,600 for low yielding plants up to $15,000 for high yielding in the first year ($14,500–24,300 in the second year). Returns based on $2.00 per bunch (assuming low plant losses) range from $18,000 to $54,000 (low to high yielding plants) in the second year to $36,000 to $63,000 in the third year. Net returns therefore range from –$27,000 in the first year, $2,100 to $25,800 in the second year and $14,500 to $32,200 in the third year. Such wide variation in returns shows the importance of variety performance to the viability of this enterprise. The sensitivity of net returns in relation to yield and price is summarised in the graph on the following page.

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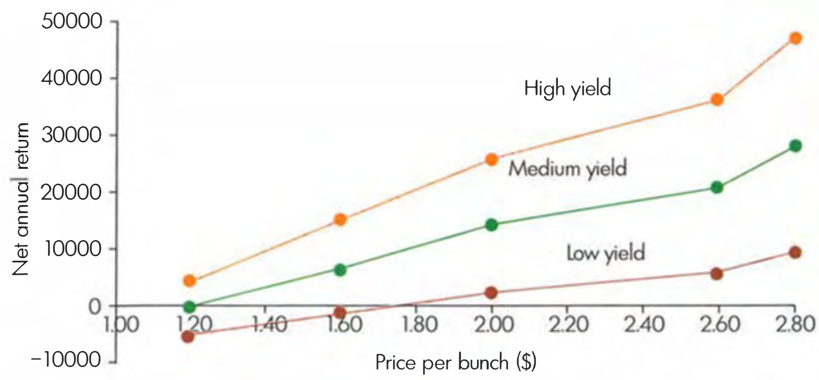

Returns from 1 ha of ixodia at first harvest

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Kangaroo paw

Ross Worrall
Ken Young

Introduction

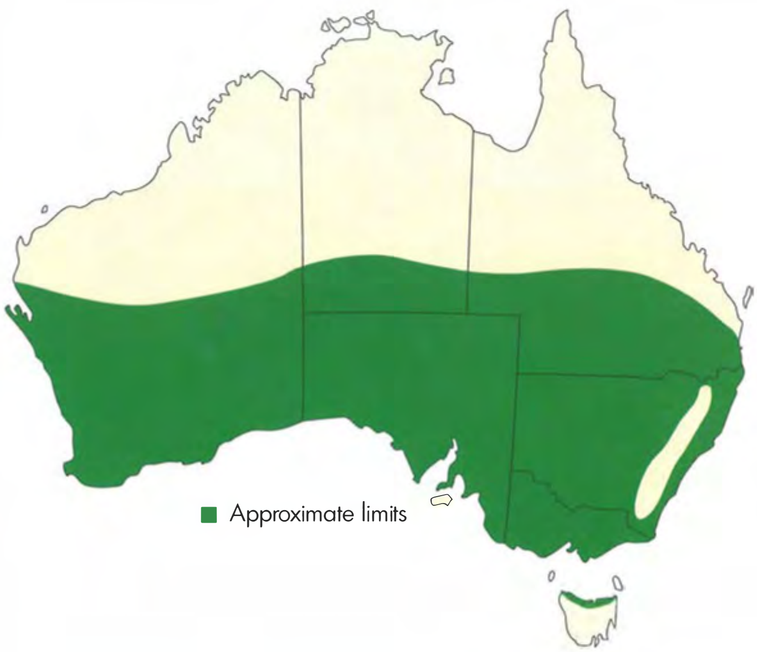
Kangaroo paws (*Anigozanthos* and *Macropidia* species) have attractive blooms that are in demand for cut flowers, landscaping and flowering pot-plant use. They are in the top three of the commercially grown native cut flowers in Australia. It is only through innovation that Australia will maintain or expand its share of the world market. Australia has been the major source of new varieties, although Israel is now also producing them. There is a need for higher yielding, more disease resistant clones, especially of the brighter colours, particularly yellow, and to extend the flowering season. The introduction of PBR (plant breeders rights) has made it possible to receive royalties for Australian-developed plants grown overseas. Few successful new varieties have been developed in recent years.

There is now a trend to produce more flowers under protected cultivation. The unique *Macropidia*, with only one species in the genus (which is closely related to *Anigozanthos*), is in high demand but difficult to propagate and grow. Potential for the expansion of the industry mostly lies in overseas markets, especially Japan. However, there is increasing competition from other countries. The largest cost is transport. Any savings have the potential to dramatically reduce costs.

Both horticultural (growing and harvesting–packaging) and marketing skills are very important in the production of kangaroo paws. They are not considered a difficult crop to grow compared with many other cut flowers, especially the *flavidus* hybrids. However, proper scheduling of harvesting and marketing is quite important.

Markets and marketing issues

In 1994, about 53% of flowers were sold domestically: 15% locally, 15% in flower markets and 23% to wholesalers. Australia supplies 94% of Anigozanthos imported into Japan (4.6 million stems in 1995) Other smaller markets are the USA, Europe and, increasingly, Southeast Asian countries. The biggest expansion in markets will be for export sales. However, there is keen competition for the overseas markets from other large producers, such as California and Israel. Major competition for the European market is from Israel. Whilst



Israeli production is 'off-season' to ours, Israel's closeness to Europe and relatively low freight rates means it can sell at a lower price than us and achieve a satisfactory return. This tends to 'stabilise' returns from Europe to that for a generic commodity. Zimbabwe is also emerging as a major competitor for the European market. The USA and Canada take only small volumes of flowers in the 60–90 cm stem-length range.

There are currently few new plantings of kangaroo paws for cut flowers in WA although the position in the eastern States seems brighter. Part of the reason for this is that there have been few new high-performing cut-flower varieties released in recent years and the industry largely relies on varieties developed many years ago. Competitors such as Israel are undertaking breeding and development programs.

Flowers may be directly exported by larger growers, or through agents. In Japan, flowers may be sold at auction or directly by arrangement through importing agents. Different markets may have different preferences. For example Japan prefers longer stems (up to 150 cm) and flowers with 'clean' vibrant colours, especially yellow. The strongest market is in September–October. In contrast there is a niche market in Europe at Christmas time—mainly for red kangaroo paws 70–100 cm long—with smaller volumes in the New Year. Colour preference changes frequently.

Key statistics

Approximately 4.3 million flowers were exported to Japan in 1995, mostly originating from WA and NSW. There is also a significant local market (3.9 million flowers in 1994). From 1993–1995 exports to Japan grew by about 20% per year.

Production requirements

Soils must be well drained, with slightly acidic sandy loams preferred. Some varieties are particularly sensitive to phosphorus and a soil test is recommended, especially for previously cultivated areas. Sites should be frost free. Although the foliage may not be damaged, flowers may be severely degraded by a light frost (i.e. –0.5°C), even in the bud stage. Plants may be grown in well-ventilated greenhouses for earlier flowering and to protect them from weather damage. However, high temperatures may result in severe flower fading, especially of the red varieties. High summer temperatures limit production areas to approximately south-eastern Queensland and south in the eastern States and the south-west of Western Australia. *A. flavidus* and its hybrids are generally much hardier.

The approximate limits of commercial production are given in the accompanying map. However, many microclimates in this area may not be suitable for the reasons outlined above. Similarly, it may be possible to grow plants in other areas. This can be determined only by trial plantings before starting full-scale production.

Adequate irrigation using high quality water is usually necessary for maximum production and to extend the flowering season, although production areas with high summer rainfall on the east coast may have little need for irrigation. Extended periods of wet weather will also exacerbate

Field planting of kangaroo paw for cut-flower production disease problems. Provided that the area is well drained, and flood and frost free, flatter areas are preferred for ease of cultural operations and harvesting. Availability and cost of transport to market or export airports should also be considered.

About the authors

Ross Worrall (BScAg(Hons), MScAgr, PhD, MTeachStud) is a senior research horticulturist with NSW Agriculture. He has specialised in the breeding and development of Australian native plants both as cut flower crops and pot plants since 1972.

Ken Young is an experienced grower and exporter of, and consultant on, Australian native cut flowers.

See *Key contacts* for the authors' addresses.

Varieties

Most plants cultivated today are hybrids or selected clones, usually produced by tissue culture in a number of laboratories in Australia. *A. flavidus* hybrids are especially popular, especially in the more humid areas of the eastern States due to their resistance to most of the common pests and diseases. There are at least 100 varieties available.

Taller (approximately 1 m) varieties with clear bright colours, especially yellow, are favoured for cut-flower production. However, smaller varieties may have a place in the mixed bouquet market. The most commonly grown cut flower varieties are 'Yellow Gem', 'Big Red', *A. pulcherrimus* (orange and yellow forms) and the 'Bush Gem' series, especially 'Dawn', 'Noon' and 'Sunset', with smaller amounts of *A. manglesii* and *Macropidia*. Some other cut flower varieties are 'Bush Ranger', 'Bush Emerald', 'Bush Haze', 'Gold Fever', 'Bush Harmony', 'Bush Ruby', 'Ruby Delight'; *A. rufus*, A. *bicolor*, 'Regal Claw', 'Orange Cross' and 'Royal Cheer' .

Agronomy

After a suitable site is selected and drainage installed , if necessary, a basal dressing of fertiliser or chicken manure is incorporated into the beds, especially in poor sandy soils. In the field, the distance between beds (usually 3–4 m) will depend on the equipment to be used for cultivation and transport of flowers. Failure to allow for free movement will greatly increase production and picking costs.

Macropidia fuliginosa (black kangaroo paw)

Within beds, there may be up to three rows 1 m apart, and plants are usually spaced 1 m apart within rows. Break rows every 50 m or so to allow for efficient vehicle movement. Beds are often raised to provide better drainage, especially in the eastern States, where the use of weed mats and mulches is also common. Planting in spring/ autumn to avoid very hot weather is preferred, especially on black weed mat. Applying fertiliser through the irrigation system is the most satisfactory method of fertilising kangaroo paw, especially if weed mats or mulches are used. Fertilising should be carried out during the growing season, especially from mid autumn to mid spring.

Plants will first flower about 6 months after planting, then at their normal time each year. Full production will be achieved in the second to third year. The number of flowers will increase beyond this but the quality will be reduced, necessitating severe pruning (slashing). Some species, such as *A. manglesii*, are best treated as annual or biennial crops. The most time and labour-critical operation is harvesting. Flowers must be harvested at the right stage for maximum quality, and processed, packed, cooled and transported to market promptly. Most varieties have flushes, therefore a mixture will help to even out production over a greater period.

Basic equipment and facilities required are a processing shed with facilities to treat flowers with fungicide/insecticide and to grade, bunch and box flowers, forced air cool room, buckets, chemicals, good quality water, tractor/ transport vehicles for site preparation and movement of flowers, slasher, spray equipment for pest and disease control, an irrigation system and access to refrigerated transport.

Pest and disease control

Ink disease of kangaroo paws (blackening of the leaves and flowers) is a widespread problem, especially in the more humid areas (e.g. coastal NSW) and under protected cultivation. Some varieties are much more susceptible than others. Ink spot is a response to a wide range of stresses e.g. insect damage, nutrient imbalance and pathogens (esp. *Alternaria).* Rust (*Puccinia haemodora*) is also a serious disease which causes typical rust pustules (blisters) on the leaves. Development of rust is favoured by hot, wet conditions, as are a range of crown and root rots caused by a variety of fungi (e.g. *Pythium, Fusarium, Phytophthora, Sclerotinia,* and *Rhizoctonia).* Young plants in poorly drained soils are especially at risk. Petal blight or grey mould (*Botrytis cineria*) may also be a problem, especially in cool damp conditions. Severity of infection of these diseases can be minimised by the use of resistant clones (usually *flavidus* hybrids), avoidance of environmental stresses, good air circulation and trickle irrigation to avoid wetting of foliage, and use of fungicides. An annual slash or slash and burn may be effective in removing infected material. Disease-free planting material is also essential.

Key message

- Approximately half of production exported.
- Significant competition from other countries.
- Expansion of export markets 20% per year during 1993–1995.
- Low rate of expansion of domestic sales in recent years.
- Need for new varieties to compete.

Compared with many exotic flower crops kangaroo paws are relatively free of pests. However, for the production of high-quality blooms a pest-control program may be necessary, especially if flowers are to be exported. It is essential to reduce insect populations to low levels before harvesting because most disinfestation treatments are only partly effective at levels that do not damage the flowers. Some problem insects are aphids, leaf miners, bud worm, thrips and small, leaf-chewing caterpillars. Most of these pests are relatively easily controlled by the application of an appropriate insecticide. Slugs and snails may also be a serious pest, especially of young plants in the greenhouse and in cooler areas. Susceptibility of species/clones to slugs and snails varies widely, with *A. flavidus* and hybrids

Gross margin analysis, year 2–3, for export material, 5000 plants/ha

Costs	($/stem)
Sale costs and freight to Japan	0.41
Harvesting, processing packaging and freight to Sydney	0.18
Production costs	0.05
Plant amortisation	0.01
Total costs	0.65
Returns	($/stem)
Sale price ($/stem)	0.85
Gross margin/stem ($)	0.20
No. stems/ha (20 stems/plant)	100,000
Gross margin /ha ($)	20,000

generally being more resistant. Control is by good hygiene and spray or pellet application of a molluscicide

Birds may cause extensive damage to flowers by breaking stems and biting off flowers, especially if other flowers are scarce. Control is by netting or human presence.

Weeds may become a major problem, especially in the eastern States. Mechanical control on a large scale is often difficult due to the herbaceous nature and habit of the plant. Plastic weed mat or mulches are very popular with commercial cut-flower growers in summer rainfall areas, especially to control broadleaf weeds. Care, however, must be taken with black weed mats due to elevated temperatures that occur under the mat. Small plants are especially vulnerable. Mowing or knock down herbicides are used for inter-row weed control. Grasses can be controlled with post-emergent herbicides. Some herbicides may cause damage to, or reduce the growth rate of kangaroo paws. Phytotoxic effects may vary with the rate, method of application and clone. Check to ensure that the herbicides you want to use are registered in your State for the intended purpose.

Harvest, handling and postharvest treatments

Flowers are usually harvested when the first one to three florets on the spike have opened. Harvesting at an earlier stage (in bud) may cause a condition known as 'bent neck'. Some growers leave at least 20 cm of the stems of *A. flavidus* hybrids to allow development of secondary flower spikes. However, the resulting flower stems may be small and dry spikes are a danger to pickers. As soon as possible after harvesting, flowers should be placed in water or a preservative solution to prevent wilting . Flowers must also be cooled as soon as possible.

After harvest, stems are usually re-cut to the desired length and bunched into five-stem units (10 stems if short, i.e. < 70 cm). Bunches are then usually sleeved into a micro-punched flower sleeve. Flowers are then disinfected by complete immersion in a Cislin®, Rovral® (or similar) mix to kill insects and to control *Botrytis*. Some growers, especially in WA, disinfest with the above mixture and dry the flowers before sleeving. Currently, insecticidal dips such as Cislin® would appear to offer the most effective means of disinfesting flowers. Treatment of kangaroo paws with aerosols, such as dichlorvos or pyrethrin, is moderately effective. Some growers use a combination of insecticidal dip followed by aerosol treatment. Before using pesticides check that they are registered for use on flowers in your State.

Left: *Anigozanthos manglesii* in the wild. There is limited bush picking of this species which is the floral emblem of Western Australia.

Right: *Anigozanthos pulcherrimus.* This species is both cultivated and bush picked.

Freedom from live insects is necessary for the export of flowers from Australia, especially to countries with strict quarantine requirements, such as Japan and the USA. Live insects on flowers will require fumigation or destruction of the flowers in these markets. Fumigation may damage the flowers and will cause a reduction in auction prices, delays in selling and a reduction in consumer confidence. Insect contamination causes similar problems on the domestic market.

Use of pulsing solutions containing sucrose after harvest can extend the vase life of kangaroo paws. However, considerable variation exists in current recommendations, which range from 2–20% sucrose and above. Acidification of the solution with citric acid at 200 ppm and a wetting agent may also improve vase life. Other chemicals, such as HQS (hydroxyquinoline sulfate) at 200 ppm, may also be effective. Individual growers should check that chemicals are registered for the intended use and experiment with rates and times (usually 12 hours) to find the best treatment under their conditions with the varieties grown. Use clean buckets and water at all times.

Kangaroo paws should be stored at low temperatures (~2°C) and a high relative humidity (95–98%), including during pulsing. Forced air cooling should be used to reduce flower temperatures as soon as possible after harvesting, and again after flowers are packed into cartons. Flowers should be at less than 5°C at dispatch. The vase life of kangaroo paw flowers is reduced by cold storage and storage on the farm should be limited to no more than a few days. The maximum total storage time should be no more than about two weeks, and preferably less than one week over the entire marketing chain.

Economics of production

The 'typical' estimated start-up costs for one hectare, not including land, machinery, clearing, labour, fencing or structures, is about $18,000 in NSW and south-eastern Queensland. This includes operating costs for one year. With little mechanisation, up to one years labour could be required to establish 2000 plants. It is emphasised that costs will vary widely from site to site, even in the same locality.

The kangaroo paw export industry has reached a relatively mature stage with significant quantities having been exported for a number of years. There are also a number of competitors on the international market. A 'typical' gross margin analysis is presented below for flowers exported to Japan. It should be emphasised that the net return to the grower (after sales and freight) can vary considerably with variety (over a twofold difference) and time of year (over a fivefold difference). As can be seen from the gross margin figures, if other sale prices are substituted, both a profit and loss are possible, depending on variety and time of year. Marketing knowledge and skills are needed to maintain profitability. It may also be very difficult to sell certain types at particular times of the year. Any change in the sale price, freight costs and the Yen/$AUD exchange rate, all of which are largely outside the control of the grower, will also have a dramatic effect on the gross margin. Due to these risks, and to spread costs and labour, it is recommended that kangaroo paws be grown in conjunction with other crops and that a range of varieties be grown.

Processing, packaging, and sales and freight costs will be very much reduced for the domestic market due to the less stringent quality requirements. The sale price is also often much lower and the market relatively small.

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Key references

Worrall, R.J. (1996). *Anigozanthos* and *Macropidia* (kangaroo paws). In: Johnson, J. and Burchett, M. (eds.). Native Australian Plants, Horticulture and Uses. University of NSW Press, Sydney.

Gollnow, B. (1995). Getting Started in Native Cut Flower Production. NSW Agriculture, Orange.

Many State Departments of Agriculture, especially WA, have numerous publications on Australian native cut flowers in general, and kangaroo paws, in particular.

Suppliers of tissue cultures, especially in WA and NSW, may also supply cultural notes.

Numerous articles also appear in *Australian Plants* (Sydney) and *Australian Horticulture*.

NSW Christmas bush

Ross Worrall

Paul Dalley

Introduction

NSW Christmas bush (*Ceratopetalum gummiferum*) has been grown and sold as a filler cut flower in the Sydney area for well over a century. It makes an excellent cut flower. The vase life of quality 'flowers' (the red sepals develop after the white flowers) can be up to three weeks. The foliage alone also has some use in flower bunches. As its name implies, it has become associated with Christmas, particularly because the bright red sepals, which contrast well with the green foliage, develop around that time of the year. Association with Christmas is both a strength and weakness.

Demand is strong on the local market immediately before Christmas, with the price dropping dramatically afterwards. Flowering times are quite variable. Often the red sepals develop after Christmas in the Sydney area, when the price is low. Consequently, there is a move to establish an alternative name for the plant, e.g. festival bush.

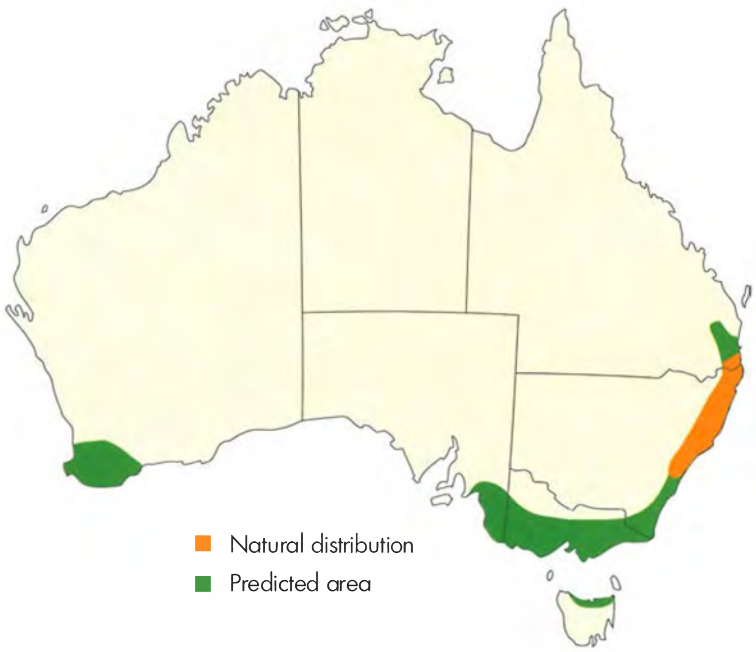
The quality of flowers on the local market can generally be considered to be quite low in terms of grading and postharvest life. There is a strong demand for high quality flowers in the Japanese market, especially before the Japanese New Year.

Current production is largely based on one early variety, 'Albery's Red'. New varieties need to be developed so as to spread harvesting times in any one locality. There are also various challenges facing the culture of Christmas bush. Hot dry winds, especially at flowering time, may cause a complete loss of the crop. Nevertheless, although there have been some losses under adverse conditions, plants should last many years if properly cared for. The range of environments in which Christmas bush can be successfully grown commercially has yet to be fully determined.

Both horticultural (growing, harvesting and packaging) and marketing skills are highly important in the production of Christmas bush. Especially critical is the ability to schedule harvesting and marketing.

Markets and marketing issues

Bunches sold on the domestic market have a variable composition of lengths and sizes, both within and between bunches. Flowers for export are



more carefully graded, principally on stem length. Other factors also taken into account are the number of sepals on the stem, their colour and how they are presented, and the total volume of the stems. There is also a specified number of stems in a bunch. Although the price received on the export market is much higher than from the domestic market, grading costs and wastage are also much higher.

The principal market for fresh cut flowers is Sydney, with approximately 500,000 flowering stems being sold in 1995. Relatively small quantities are sold in Brisbane and little in Melbourne. Early season prices are better in Brisbane than in Sydney. Large quantities are also sold directly to wholesalers and florists. A relatively small quantity (approximately 1500 boxes) was exported in 1996–97, largely to Japan. Flowers are either exported directly by the growers or forwarded through agents. Once in Japan, flowers are sold either by auction or direct to wholesalers.

The timing of sales is critical in all markets to achieve the best price. High prices are currently obtained for flowers on the Japanese market. Current prices can be expected to fall as supply increases from extensive new commercial plantings over the past two years. There are now some 30,000 plants under cultivation compared with 8,000 plants in 1994. The expansion of plantings is expected to continue in the immediate future. Total production in 1999 is expected to be 2.5 million stems, compared with 0.5 million in 1995. The expected price drop may be partly offset by availability over a greater period and the demand for new colour forms.

Production requirements

The primary requirement for the production of quality flowers is protection from hot dry winds, especially at flowering time. These can cause an almost complete loss of flowers in a matter of days, or at least a significant reduction in quality, especially vase life. Adequate water is also important, especially from flowering time to harvest. Plants should be irrigated regularly. Two- to three-year-old plants require about 4 L/day. Established plants will tolerate moderate frosts to about –4°C.

Key statistics

An estimated total of 1500 boxes of Christmas bush (120,000 stems) were exported in 1997–97. More Christmas bush is still sold on the local market which was estimated at 500,000 stems in 1994. In the last two years, over 30,000 Christmas bush have been planted. These new plants have yet to come into full production.

Soil type does not appear to be important, provided drainage is good. However, ability to tolerate alkaline soils has yet to be determined. Christmas bush is intolerant of salty water.

The species occurs naturally in rainforest and moist gullies in coastal NSW. It has been grown commercially near Toowoomba in Queensland and coastal areas of Victoria (see map). Its commercial performance in other parts of Australia, such as south-western Western Australia is not known. However, in a suitable microclimate it may well be successful. It should also be noted that, even within areas marked on the map, some parts may not be suitable due to local conditions.

Close-up of flowers (white); the red sepals are beginning to develop

Young plant (about 2 years old) of 'Albery's red', showing a combination of mulch and mat used for weed control. Splitting the weed mat makes it easier to apply fertiliser.

Varieties

It is strongly recommended that selected clones be used, rather than seedlings, which may be highly variable. The most commonly grown variety is 'Albery's Red'. This is compact, dark red in colour, and early and free flowering. Almost all new plantings are of this variety. It is well accepted in the Japanese market and often brings the best price on the Australian market. There remains a need, however, to extend the flowering season and introduce a greater range of colours.

One variety which shows particular promise is 'Shiraz' (syn. 'Christmas Belle'). It flowers 2–4 weeks later than 'Albery's Red', depending on location, and is a darker red. Initial shipments have been well accepted by the Japanese market. Two white varieties are 'Silent Night' and 'White Christmas', the second of these being less vigorous and more compact. There has been a good response from the Japanese market to trial shipments, although there are some problems with brown spots on white sepals. The spotting can result from rain, overhead irrigation or condensation. There is also a range of other colours available, especially pinks, some of which show particular promise in terms of plant form and vase life of the 'flowers'. It is anticipated that a wide variety of new clones will be released over the next few years.

Agronomy

After a suitable site is selected, and drainage installed if necessary, a basal dressing of fertiliser or chicken manure is incorporated into the beds. In the field, the distance between beds (usually 4 m) will depend on the equipment to be used for cultivation and transport of flowers. Failure to allow for this will greatly increase production and picking costs. Within beds, plants are usually spaced 1–2 m apart. Beds are often raised to

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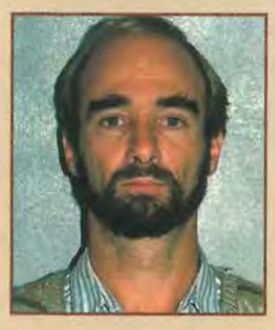

Paul Dalley is a cut-flower grower, nurseryman, consultant and TAFE lecturer and has had extensive experience in the development of Australian native cut-flower crops for export.

See *Key contacts* for the authors' addresses.

provide better drainage and weed mats/mulches are also commonly used to control weeds. Planting in spring/ autumn to avoid very hot weather is preferred, especially on black weed mat. Trickle or drip irrigation is generally used, so as to avoid wetting the foliage.

Commercial production starts 1–2 years after planting, depending on the size of transplants. The most time and labour critical operation is harvesting. Flowers must be harvested at the right stage for maximum quality and processed, packed, cooled and transported to market promptly. Picking of varieties at any one location generally takes place over 3–5 weeks. A mixture of varieties will help to extend production over a greater period.

Christmas bush responds well to fertiliser the application of which is essential for commercial production. However, no fertiliser should be applied for 3–4 months before harvest, to reduce the risk of new shoots overgrowing the 'flowers', and thus reducing quality. The use of slow release fertilisers such as 9-month Osmocote® or Nutricote® in a once-a-year application after harvest, combined with pelleted chicken manure applied in January and April, appears to give satisfactory results. These may be supplemented with additional liquid fertiliser applied through the irrigation system. As a guide, 20–30 grams of slow release fertiliser should be applied to 1–2-year-old plants (at least 1.5 m high) with an equal amount, in terms of nutrient content, of pelleted fowl manure. Plants are not particularly sensitive to phosphorus fertilisers.

Proper pruning of the bush is vital for maximum production and usually takes place as flowers are harvested or immediately afterwards. Any unharvested branches are cut back to 25–50% of their original length. The main trunks should be cut back to 2–2.5 m to facilitate harvesting. The general aim is to leave about 25% of the original foliage or regrowth will be reduced.

Typical gross margin analysis at year 5 for export material, 2000 plants/ha (mid north coast of NSW)

Costs	($/stem)
Sales and freight	0.71
Packaging and processing	0.19
Harvesting and growing	0.17
Plant costs	0.07
Total costs	1.14
Returns	($/stem)
Sale price ($/stem)	1.39*
Gross margin/stem ($)	0.27
No. of stems (50 stems/plant)	100,000
Gross margin/ha ($).	27,000

* Actual price in 1996–97 was $3.20. This is expected to fall with increasing supply.

Key messages

- Well established domestic industry.
- Significant new plantings have taken place.
- New export industry.
- No significant competition from overseas countries.
- Needs specific climatic conditions.

Pest and disease control

The main insect pests are leaf-curling psyllids, which often appear on new growth. They are difficult to control, even with repeated applications of insecticide. Scale insects can also be a persistent problem, particularly if plants are not growing strongly. Other pests are aphids, caterpillars and thrips which can attack new shoots and flowers, although they have not been a major problem to date. It is important to reduce pests and other insects to a low level in the field, especially if flowers are to be exported. The disinfestation treatment commonly used is an insecticidal dip. This is only partially effective, therefore the chance of live insects contaminating flower shipments can be greatly reduced if the insect population is reduced before harvest. Root diseases may also become a serious problem in sites that are not well drained.

Close-up of cv. Albery's red

Young high-density planting of Albery's red

Use of weed mats or mulches will greatly reduce the need for weed control. Glyphosate has been used to control weeds under mature plants, with no toxic effects apparent to date. The long-term effect of other herbicides is unknown at this time. Note that it is essential to check the registered uses of pesticides in your State before applying them.

Harvest, handling and postharvest treatments

Basic requirements for production and handling are a processing shed with facilities to treat flowers with fungicide/ insecticide and to grade, bunch and box flowers, a forced-air cool room, buckets, chemicals, good quality water, tractor/ transport vehicles for site preparation and movement of flowers, a slasher for weed control, spray equipment for pest and disease control, an irrigation system and access to refrigerated transport.

Harvest time is early November to mid December on the north coast of NSW and in south-eastern Queensland, with later harvests in cooler areas. Christmas bush is sold by the stem in 40, 50, 60, 70 and 90 cm lengths for export markets. Leaves are stripped from the lower 10–20 cm, depending on their length. Bunches of 3, 5 and 10 stems are made, depending on their length and volume. They are dipped in an insecticide/fungicide solution (e.g. Cislin® & Rovral®: check the registered uses in your Sate) and sleeved when nearly dry. Packed boxes should be cooled before transport. The domestic market prices by the bunch and will accept a bunch of mixed stem lengths, from 5–25 stems, depending on their size and fullness.

Stems should be placed in water as soon as possible after harvesting. They should be cooled to 8–10°C for overnight storage or to 2–5°C for longer periods. Use clean water and buckets. Dilute citric acid and bleach in the water may improve vase life.

Economics of production

A one hectare planting of 2000 plants will keep one person fully employed, with additional labour required at harvesting time.

However, due to the strongly seasonal nature of labour requirements and risks (growing and financial) associated with a single crop, it is recommended that NSW Christmas bush be grown in association with other cut flower crops. Current commercial plantings range from about 200 to 2000 plants. The estimated start-up cost for a hectare, not including land, machinery, clearing, labour, fencing or structures, is about $16,000 in coastal NSW. This includes operating costs for one year. With little mechanisation, up to one years labour could be required to establish 2000 plants.

Growing and harvesting the Christmas bush for export accounts for only about 15% of the final wholesale price. Processing and packaging also account for only 17% of the final sale price. By far the greatest costs are sales and freight—in total accounting for 62% of the total cost of production. Any change in the sale price, freight costs and the yen–dollar exchange rate, all of which are largely outside the control of the grower, will have a dramatic effect on the gross margin. Processing, packaging, and sales and freight costs will be very much reduced for the domestic market due to the less stringent quality requirements. The 1996–97 gross margin for one hectare (2000 plants) of five-year-old plants with flowers sold in Japan was more than $200,000. However, in the long term a gross margin of $27,000 is more realistic for material sold on the export market as prices fall due to increased supply. It is estimated that over 30,000 plants have been planted over the past 18 months. If all labour was costed, the gross margin in 1996–97 selling all material on the domestic market would have been between approximately –$10,000 and +$10,000/ha, depending on time of harvest. It is obvious that the export market is far more profitable, but it requires a higher quality product.

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Dalley, P. (1996). Christmas Bush: Cut Flower Cultivation. Mountain Nursery, Trappaud Road, Kempsey.

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Protea, leucadendron and waratah

David Tranter

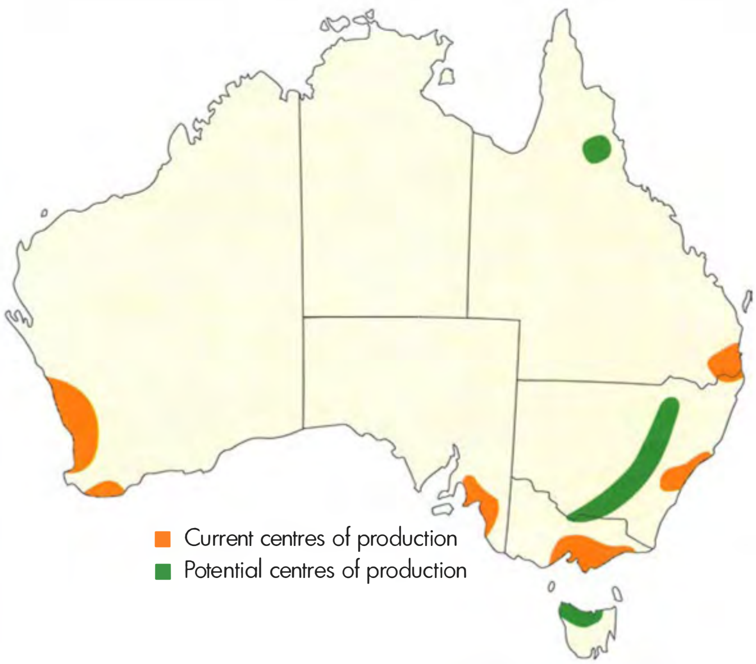
Introduction

The genera *Protea*, *Leucadendron* and *Telopea* ('waratah') are members of the Proteaceae family, the first two being native to South Africa and the third to Australia. They tend to have long woody stems and a relatively long vase life and they look so 'different' and 'exotic', that they have established a niche within a much larger market based on 'traditional flowers'. Other members of the family not dealt with here include *Leucospermum* (Pincushion), *Serruria* (Blushing Bride), *Banksia* and *Dryandra*. They are usually grown out in the open as field crops, with only windbreaks for protection (Fig. 4), waratah in the (eastern) summer rainfall belt, and protea and leucadendron in both winter and summer rainfall belts.

Australian production is greater than the domestic market can absorb, therefore further expansion must be export orientated. Elements in our favour include diversity of growing season and capacity to supply in the northern hemisphere winter. There is little vertical integration in the industry—the grower either supplies an exporter or exports in his own right through an overseas import agent. In recent years, demand has been relatively flat, after years of sustained growth; there is evidence that this is due in part to New Zealand competition. Producing flowers for export is not a business for the dilettante but, for those who are prepared to learn and pay close attention to detail, the prospects are relatively good. What is needed is dedication, intelligence, commitment to quality, and an ability to search out and get the information that is needed. Benchmark details for the industry are to be found in *The Australian Wildflower Industry, a Review*, published by RIRDC (see Key references).

Markets and marketing

The main growing centres are WA and Victoria. The main domestic markets are Sydney, Melbourne and Brisbane. The greater part of U.S. demand is supplied by home-grown product from California and Hawaii. The European market is supplied mainly from South Africa, but there are windows of opportunity for high quality Australian product; for example from All Saints Day (1 November) to Christmas (Queen Protea) and February–March (Protea Pink Ice).



Our main markets are in East and Southeast Asia (particularly Japan). These are close to us, the flights are direct and the airfreight is relatively cheap. Major points of entry are Tokyo, Osaka and Fukuoka. Secondary markets are emerging through Nagoya, Sendai, Hiroshima, Hokkaido, Taipei, Seoul and Hong Kong. Most product to Japan is auctioned on consignment; some is sold at fixed price. Elsewhere, markets are less structured, and the volume that any one importer can handle is therefore much smaller.

Product is sent by airfreight in reinforced cardboard boxes. Airfreight costs are structured on a sliding scale, the bulk being shipments of about 1000 kg. That requires a plantation of 5–10 ha or consolidation of product from several plantations. Up till now more leucadendron has been exported than protea, with very little waratah (this would improve if the waratah season could be extended). The average FOB value of product exported from Australia is about $7/kg, but fixed price customers will pay more if it is top quality. Quality constraints are strict and, except for high-value items, returns are slim when the exchange rate rises above 90 Yen/$A. Protea and leucadendron together constitute about 20% of Australian flower exports.

The King Protea (*Protea cynaroides*), a high-value export flower
Courtesy: FECA

Production requirements

The capacity of proteaceous species to scavenge minute concentrations of phosphorus from deficient soil makes them vulnerable to toxicity when the phosphorus content of the fertiliser is high. Fertilisers must be applied with caution, preferably by 'fertigation' using formulae suited to the soil. Protea and leucadendron are adapted to well drained, nutrient-poor soils and winter rainfall. They are vulnerable to Phytophthora root rot and fungal leaf diseases associated with summer rains. Waratahs, by contrast, are adapted to summer rainfalls. They are less vulnerable to phosphorus toxicity, but they do require deep, free-draining soils. Proteas are more vulnerable to frost than leucadendron and waratah. Leucadendron colour develops better in cooler climates.

To avoid Phytophthora, it is best to plant in mounded rows (Fig. 4), taking care not to mound across any gullies—plantations should be shaped to shed the rainfall as quickly as possible. All commercial varieties do better in acid rather than alkaline soils, the ideal being a pH of 5–6. For more detail on production, consult Gollnow (1997) or IHD Victoria (1995).

Varieties

There are about 20 commercial varieties, not all of which will do well at any particular site. It is important to choose target crops with care, and put in a trial plantation in parallel with the target planting so failures can be replaced with cultivars more likely to succeed. Those in demand include :

- *Leucadendron discolor* (male) – yellow with red centre
- *Leucadendron* 'Inca Gold' – gold and green
- *Leucadendron laureolum* – yellow (early greenish yellow stage preferred)
- *Leucadendron* 'pisa' – yellow flowers, silver foliage

About the author

David Tranter grows protea, leucadendron and waratah on a small farm at Robertson, NSW. He is a foundation member of the Australian Flora and Protea Growers' Association and Honorary Life Member of the Flower Export Council of Australia. See *Key contacts* for address.

Leucadendron 'Safari Sunset', a New Zealand cultivar, autumn tones

- *Leucadendron* 'Safari Sunset' – dark red with golden autumn shades (Figs 2 and 4)
- *Protea cynaroides* (King Protea), in pink (Fig. 1) and white, both large and small
- *Protea grandiceps* (Princess Protea) – various shades of salmon to bright pink
- *Protea magnifica* (Queen Protea) – in varieties of pink and white
- *Protea neriifolia* (Mink) – in varieties of pink and white with a coloured fringe
- *Protea* 'Pink Ice' – an Australian cultivar
- *Protea repens* (Honey Protea) – in varieties of pink, red and white
- *Telopea speciosissima*, NSW waratah, in red (Fig. 3), pink and white
- Hybrids of *Telopea speciosissima* and *T. oreades* (Victorian waratah)

Other cultivars and hybrids are available that might do better at your site. If the flower has a long straight stem, a clean bright colour and a long postharvest life, there is likely to be a demand for it in the marketplace by virtue of its novelty. Tubestock may be obtained from specialist protea nurseries which advertise in Australian floricultural publications. Guidance on which varieties to choose is best obtained from State primary industry agencies, other commercial growers, and industry associations like the Australian Flora and Protea Growers Association (AFPGA) and FECA. It is most important to choose known cultivars rather than seedling stock, most of which will have little commercial value.

Agronomy

The ideal plantation has an easterly, north-easterly or northerly aspect with a convex slope mild enough to allow safe tractor access to every point. To avoid root rot, the soil should be shaped in parallel mounded rows, far enough apart (~ 4 m) to allow unobstructed tractor access to fully grown bushes (Fig. 4). Trickle irrigation is laid along the mounds, with irrigation points to suit the target planting interval: 0.5–1.5 m for leucadendron; 1.5–2.5 m for protea; and 2.5–3.5 m for waratah. To minimise time spent on weed control, the mounds are often covered with weed mat (Fig. 4). Best growth and finest blooms are obtained by 'fertigation' to formulae derived by skilled soil consultants on the basis of soil analyses. The alternative is to adjust the pH and nutrient content of the soil before shaping the plantation, but opportunities to do this after planting are rather limited when weed mat is used.

In general, leucadendrons begin to flower in their second year; and proteas and waratahs in their third, but another year is required for a commercial crop. If the plant is healthy it will live for 10 years—waratah for at least 20 years. The main requirements after planting are pruning and spraying (to control fungal diseases and insects). Pruning is usually done in winter or early spring until the plant starts to flower; thereafter, much of the pruning can be done during harvest. In general, 2 ha of intensive planting is as much as one person can properly attend to on his/her own.

Key messages

- Flower growing is hard work.
- There is a lot to learn.
- Identify your 'critical mass' threshold.
- Consult State floriculture experts.
- Join an industry association.

The New South Wales Waratah, *Telopea speciosissima* (large variety)
Courtesy: Bob Harris

Pest and disease control

Flowers grown for export need to be sprayed with insecticide every few weeks to meet plant quarantine requirements. The most difficult pest to eradicate is scale, which can be controlled with white oil when the larvae are at the crawler stage (early and late summer). Waratah suffer from leaf miner and bud-tip borer and need to be sprayed weekly from December to March when the buds set. Protea and leucadendron require fungicide to combat leaf disease, particularly in summer rainfall areas, the worst diseases being Elsinoe, Drechslera and Colletotrichum. The best guide to fungicides and pesticides and their use is the Gatton College PESKEM manual (see *Key references*).

Harvest, handling and postharvest treatments

For maximum postharvest life, flowers need to be picked daily at the earliest stage that will allow them to mature. Over-mature flowers are often damaged by bees (e.g. *Protea repens*) and are difficult to pack; leucadendron are less demanding. For advice on the right stage to pick, consult your industry association or State floriculturist. To avoid desiccation, put the flowers in water in the field at the picking stage or in a shaded container and return to the packing shed within an hour of picking.

Protea need to be 'pulsed' with a bactericidal sugar solution to minimise leaf blackening, and stored in a cool room lit at approximately daylight intensity. Waratah also benefit from pulsing, which maintains their turgor. Forced air cool rooms are required for bulk throughput to ensure that cooling is rapid and thorough. For small operations, product can be stored in ordinary cool rooms in buckets of water. Export flowers must be disinfested by dipping in insecticide solutions (e.g. permethrin); or by fumigation (e.g. methyl bromide); or by exposure at 20°C to insecticidal aerosols (e.g. 'Pestigas" to activate the insects, followed by

Cash flow projection for King Protea (*Protea cynaroides*) (courtesy of Brian Freeman, IHM Pty Ltd).

1 Ha Plantation, 2200 Plants, $3/Plant	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**TOTAL**
Marketable Blooms/Plant	0	0.2	3	8	10	10	10	
Total No of Blooms	0	440	6600	17600	22000	22000	22000	
FOB Price/Stem ($)	2.25	2.25	2.25	2.25	2.25	2.25	2.25	
FOB Income ($)	0	990	14850	39600	49500	49500	49500	
Expenditure ($)								
Plants	6600	330						
Plantout Labour @$0.25/Plant	550							
In-field Irrigation Equipment	2640							
Install Irrigation (est)	600							
Soil Preparation (est)	600							
Shelter (est)	250							
Weedmat	3300							
Contingencies	500							
Establishment Subtotal ($)	**15040**	**330**	**0**	**0**	**0**	**0**	**0**	
Water (Power)	400	440	484	532	586	644	709	
Fertiliser	150	250	450	500	550	550	550	
Chemicals	800	880	968	1065	1171	1288	1417	
Weeding & slashing	450	500	550	550	550	550	550	
Spraying	450	550	600	650	700	700	700	
Pruning @ $0.60/plant	0	0	1320	1320	1320	1320	1320	
Labour @ $0.50/plant	1100	1100	1100	1100	1100	1100	1100	
Packaging @ $0.50/stem	0	97	1452	3872	4840	4840	4840	
Contingencies	500	500	500	500	500	500	500	
Harvest and pack @ $0.50/stem	0	220	3300	8800	11000	11000	11000	
Freight to city @ $3/carton	0	66	990	2640	3300	3300	3300	
Operating subtotal	**3850**	**4603**	**11714**	**21529**	**25617**	**25793**	**25986**	
Total costs ($)	**18890**	**4933**	**11714**	**21529**	**25617**	**25793**	**25986**	**134461**
Annual net return ($)	**(18890)**	**(3943)**	**3136**	**18071**	**23883**	**23707**	**23514**	**69479**
Annual net return/plant ($)	**(8.6)**	**(1.8)**	**1.4**	**8.2**	**10.9**	**10.8**	**10.7**	
Cumulative net return ($)	**(18890)**	**(22833)**	**(19697)**	**(1626)**	**22257**	**45964**	**69479**	
Operating cost/plant ($)	**1.75**	**2.1**	**5.3**	**9.8**	**11.6**	**11.7**	**11.8**	**7.4%**

the dichlorvos formulation, 'Insectigas'). Methyl bromide is now being phased out, and CSIRO has developed a phosphine alternative.

Leucadendron are usually sold in bunches of 5 or 10, except for large 'multiheads' which are sometimes sold as singles, as are most protea and waratah. Export protocol (especially for Japan) demands stems of equal length and thickness with leaves stripped away from the base of the stem. Cellophane sleeves are sometimes used to protect the bunch, minimise desiccation and improve appearance. Export boxes (less than 10 kg) are smaller than 'domestic boxes' and are made of sturdy cardboard, with a separate lid and base for added strength, and with insect-screened ventilation holes at each end for forced air cooling and fumigation.

Plantation layout showing windbreaks, mounded rows, weed-mat and spacing between rows (Harris Park, Robertson, NSW)

Economics of production

Growing protea, leucadendron and waratah for profit has a greater chance of success if it is pursued as an extension of some other agricultural activity on land already owned; otherwise the capital costs of purchasing land, facilities and equipment could be prohibitive. Given suitable land, the major establishment costs are for shaping the land, building windbreaks, laying down weed mat and micro-drip irrigation, installing header tanks, purchasing selected tube stock, and constructing a packing shed with a cool room and fumigation facilities. All this will cost at least $50,000. Production costs include picking, postharvest treatment, grading, packing and transport, according to the size of the crop. Export costs include domestic transport, airfreight and customer credit for up to 3 months (say another $50,000).

Key statistics

The current value of protea and leucadendron exports is about $5.4 million. The value of domestic production is about $10 million/year.

The breakdown of production by State given in the 1992–93 ABS Survey is:

- Western Australia 35.8%
- Victoria 19.6%
- South Australia 15.7%
- Queensland 14.8%
- New South Wales 9.3%
- Tasmania 4.6%

Given domestic markets for the product, a productive plantation of 2 ha worked entirely by the owner without hired help is capable of generating a survival income. Export plantations tend to be 5–10 ha family businesses benefiting both from hands-on efficiencies and from economies of scale (Australian experience has shown that remote-controlled investment companies are unlikely to succeed).

The table on the preceding page (Courtesy of Brian Freeman, International Horticultural Management Pty Ltd) is a model projection of likely net and gross margins for a King Protea plantation. Given assured markets for the product, the annual net return per hectare is of the order of $10,000 per year, but it is not until the 5th year that income exceeds expenditure. The same would apply to waratah. Leucadendron crops could yield a net return in the third or fourth year.

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Rice flower

Peter Beal
Cynthia Carson
Lois Turnbull
Leif Forsberg

Introduction

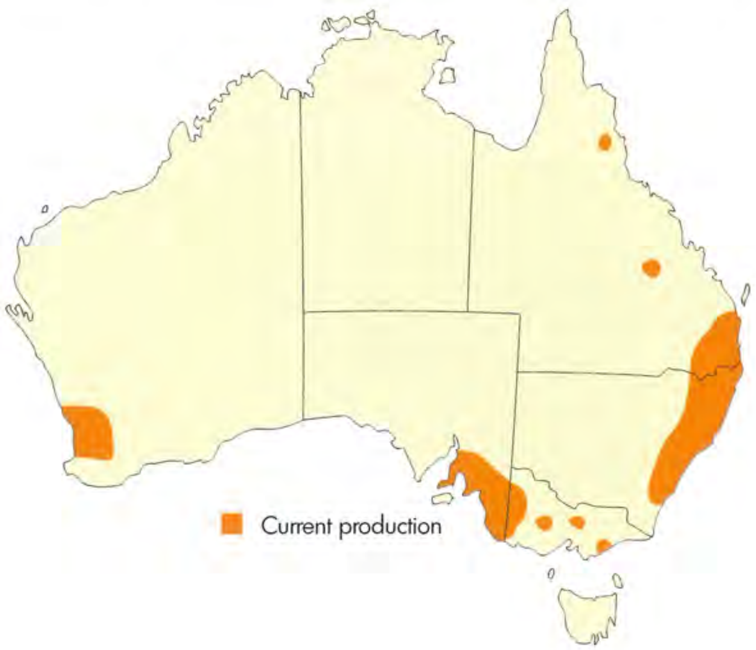
Rice flower (*Ozothamnus diosmifolius*) or 'rice flower everlasting' is an upright, spring flowering, perennial woody shrub from the Asteraceae (daisy) family, with a natural distribution in coastal and sub-coastal regions of New South Wales and Queensland. This Australian native cut flower crop, harvested solely from the wild until the late 1980s is now cultivated in all Australian States and in the United States of America. Australian grown rice flower is sold as a filler or focal filler flower primarily into the Japanese and United States markets. Rice flower has a long vase life and versatile usage, from bouquets through to hotel foyer arrangements. Fresh flower colour ranges from white to dark pink and the product can be dried and dyed.

The unique characteristics of rice flower have created an unsatisfied demand for product. The Japanese market has not been widely exposed to rice flower and the market for high quality stems should remain strong for at least the next five years. There is potential to extend the September–October production season using early and late flowering varieties, different production localities and techniques for flower preservation. Spring produced rice flower from Australia faces no direct market competition in Japan. If a year round market develops, production from Japan itself, Israel and the Americas may become a threat to the Australian industry. In both the US market and in developing markets in South East Asia, the challenge for Australian growers will be to contain costs without sacrificing quality. Processed, dried or preserved flower is likely to assume a greater role in future sales.

Rice flower can be highly productive under optimal conditions. However, poor soil drainage and susceptibility to pests and diseases limit crop performance. Successful rice flower production requires careful site and cultivar selection and appropriate growing skills to maximise productivity and minimise plant losses.

Markets and marketing issues

The Australian rice flower industry is based on export. Demand is expected to remain firm. In 1996, 500,000 stems or approximately 90% of all production was exported. High export prices for fresh product have delayed the development



Key statistics — Australia

Year	1991	1992	1993	1994	1995	1996
No. of growers	–	–	38[3]	–	–	80[1]
No. of plants	–	25,000[1]	45,000[3]	–	–	120,000[1]
Total Exports (stems)[2]	60,000	100,000	300,000	490,000	500,000	500,000

[1] QDPI surveys
[2] Exporters estimates
[3] Karingal Consultants (1994)

of markets for dried or preserved product. The major export market is Japan, followed by the United States, with test marketing into Hong Kong and Taiwan. Good prospects exist for market development in South East Asia.

Fresh rice flower is air freighted to Japan as bunches in lengths from 40 cm, 50 cm etc, to 110 cm. Extra-long stems may be sent loose. Rice flower to the US is sold as weighed bunches (normally 400 to 450 grams) of stems 40, 50, and 60 cm in length. The average return to growers, over all markets, was around 48 cents per stem in 1996.

Japan is a high priced market, with the best prices being paid for well graded, quality product harvested at the correct stage of maturity. Growers with consistent presentation and good quality can average over 60 cents per stem. Quality long stemmed pinks can return 90 cents per stem.

Plantings of rice flower varieties at harvest maturity at Helidon, Queensland

Product sold to Japan is graded on-farm or in a packing house, moved through the exporter to the freight forwarder, then air freighted to Osaka or Tokyo. Flowers are normally kept refrigerated until exit from Australia. In Japan, flowers are subjected to ambient temperatures during customs clearance and periodically through the marketing chain. Most product, excepting a minority of direct sales, is distributed to one of over 300 auctions. From the auctions, product moves through the wholesaler, via the internal freight network, to the retailer and final customer.

The USA has a rice flower industry in California of a similar size to that in Australia. Rice flower is harvested in the US spring (mid March to mid May), predominantly for use as a dried filler flower by the domestic market. The distribution chain in the US is similar to that in Japan, but the product is maintained in a cool condition, often through to the retail level. Australian product most frequently lands on the west coast of the US in San Francisco or Los Angeles.

Attractive heads of a vivid pink selection

About the authors

Peter Beal

The authors, all from the Centre for Amenity Horticulture, Redlands Research Station, Cleveland, Queensland 4163, Queensland Department of Primary Industries, have been involved in research in the production and marketing of rice flower as a cut flower crop over the last 5–8 years, funded by RIRDC.

Contributions have included germplasm collection and evaluation (P. Beal), agronomic research (L. Turnbull), identification or diseases and disorders (L. Forsberg) and marketing investigations and development of standards (C. Carson). For address details see *Key contacts*.

To maintain acceptable prices per stem on overseas markets, quality control is vital. This needs to be implemented through all the phases of growing, harvesting, packaging, transport and marketing.

Production requirements

Rice flower is grown over a wide range of climates and soil types in all States of Australia (see map) in both lower (<1000 mm/ year) and higher (>2000 mm/ year) rainfall areas. In warmer climates (e.g. south-east Queensland) high growth rates are achieved. Rice flower flowers in spring (August–October) and early summer (November–December) in warm climates. In cooler climates (e.g. Victoria) growth rates are slower and the onset of flowering is four or more weeks behind that in Queensland. Mature rice flower can tolerate frosts to –2°C and temperatures in the high 30s, particularly if soil moisture is not limiting. Prospects for cultivation of rice flower in more northern and southern (e.g. Tasmania) latitudes are still being evaluated.

Although originating from infertile soils, in cultivation rice flower performs well in highly fertile soils as evidenced by its high growth rate on acid (pH 5.0–6.0) krasnozem soils in south-east Queensland. Rice flower can be grown in soils of high phosphorus (90+ ppm) content. Adequate water supplies are needed to establish new plantings and to obtain good flowering stem length, inflorescence quality and postharvest life.

Like many other Australian native species in commercial cultivation, rice flower requires well drained soils.

Varieties

Rice flower varieties vary widely in morphology (including plant shape and height, degree of branching, leaf shape, flower shape and colour) and production characteristics (such as flowering season, stem production, inflorescence vase life, disease susceptibility and longevity in cultivation). Rice flower varieties are readily propagated from stem cuttings.

The rice flower industry is at present largely dependent on two cultivars: 'Cook's Tall Pink' (PBR No. 387) and 'Cook's Snow White' (PBR No 386). Emerging cultivars include 'Redlands Sandra' (PBR No 793), 'Dalby White', 'Dalby Pink' and 'Coles Pink No. 1'. For any one cultivar, the harvest season may be as short as 3–5 days or as long as 3–4 weeks. Planting of the three cultivars 'Cook's Tall Pink' (early season), 'Redlands Sandra' (early-mid season), and 'Cook's Snow White' (mid season) has given a continuous harvest period of 3–5 weeks during September and early October at Helidon in Queensland.

The production performance of individual clones is frequently site specific. Fine leaf cultivars perform well in Queensland, but are not suited to conditions in southern NSW and Victoria. Growers need to be active in identifying the cultivars best suited to their location. Planting stock may be purchased from commercial native plant nurseries in most States.

Agronomy

Successful commercial cultivation of rice flower requires careful site selection. The use of soils with good internal drainage, preferably with a low clay content, is recommended, together with planting on mounded beds. The wood of rice flower plants is brittle and prone to splitting. Plants should be protected against wind damage by providing windbreaks and may also be supported with trellises or flower mesh. These practices will help reduce the incidence of root and stem diseases and minimise plant losses.

Varieties suited to the growing location should be selected. High quality planting stock, free of disease and root congestion, should be sourced from reputable suppliers.

Cultivation, spraying, weed control (slasher) and irrigation equipment required will vary, dependent upon the farm situation and the production system used. Harvesting equipment, a trailer or truck for product transport, a packing shed and access to a cool room during the harvest period will also be needed.

Sizing and bunching rice flower stems in the shed

Key messages

- select a well drained soil
- identify the most suitable varieties
- use healthy young planting stock
- minimise plant losses
- Japanese market demands high quality

Satisfactory weed control can be achieved by using contact or systemic herbicides, combined with use of organic mulch or weed mat. Pre-planting soil fumigation with methyl bromide is recommended for sites infected with root-knot nematodes. Regular field spraying with insecticides and fungicides, particularly during the flowering stages, will give general protection against pests and diseases. Following planting, tip pruning of young plants will help to increase branching. Pruning after harvest will encourage regrowth for the next crop.

Little information is available on the irrigation management and fertiliser needs of rice flower. Supplementary watering is required to achieve commercial yields. Also, plants respond well to additions of NPK fertiliser. Strongly acid soils should be limed to pH 6. Some genotypes are particularly prone to iron

Developing an Australian native flower

Graham Cook was the first grower to cultivate rice flower commercially. Graham has a lifetime of experience in farming, but by 1987 he and his wife Esther were looking for a crop which would make their lucerne and cattle farm near Helidon in southern Queensland more viable and easier to manage. They were seeking something that did not need a large or expensive specialise equipment, that needed a minimum of water, and which could tolerate salty water in dry times. They looked at native flowers.

Graham and Esther Cook with their rice flower selections

After trialling (mostly unsuccessfully) a wide selection of native flowers, mainly proteas and West Australian species, they felt that the local rice flower looked the most promising and suitable for their climate. The bush-picked product was already marketed, and exporters were keen to obtain larger quantities of better quality flowers. The first commercial plantings were made in January 1988.

The hardest thing they found about bringing a new plant into cultivation is that there is simply no information available on how to grow it. Each problem must be solved by trial and error.

Graham's knowledge of farming a wide range of crops provided a wealth of experience to draw on, but the going has not been easy. Many obstacles, particularly rice flower's susceptibility to nematodes and a variety of as yet unidentified problems, have yet to be overcome.

Part of the solution lies in growing more vigorous and resistant cultivars and Graham and Esther have an extensive plant-breeding program. Esther is currently monitoring some 3000 plants grown from seed. It is a huge job, because no two plants are identical. The Cooks are looking for robust plants that regrow vigorously after harvesting. Plants must also have clear colours (no off-whites or muddy pinks) and produce at least 30 straight stems more than 60 cm long by their second harvest. About 7% of the seedlings are considered good enough for further trialling. The Cooks released two cultivars, 'Cooks Snow White' and 'Cooks Tall Pink' in 1993, and expect to release others in the near future.

deficiency. This can be readily overcome by foliar spraying with ferrous sulphate (2 g/L).

Plant densities of 0.5 to 1.0 m within rows and 2 to 4 m between rows are commonly used. High density plantings of 0.5 m to 0.75 m within the row, rather than 1.0 m, allow for significantly higher stem production per unit area and compensate for plant losses.

In mild subtropical locations, planting all year round is possible. Planting at times of extreme temperatures (summer, >28°C; autumn and winter, frosts) should be avoided to minimise the possibility of plant losses. Flower initiation in rice flower normally occurs in July in south-east Queensland, with the commercial harvest extending from late August to mid October.

In the subtropics, satisfactory growth (to 1.0 m and more) and flowering (from early spring) can readily be obtained in the first 9–12 months, with marketable stems produced in the first year. In temperate locations, satisfactory growth and flowering may take 12–18 months, with the first harvest in the second year. Commercial plants commonly have an economic life span of 2–3 years, although plants may live up to 6 or more years.

Around 200 hours of labour is required to establish a one hectare planting of rice flower, excluding annual maintenance costs. Crop husbandry would use somewhere between 100 and 120 hours per annum from the first year forward, excluding harvesting. The time input needed for harvesting will vary according to yields, but approximately 7 hours would be required to harvest, grade, bunch, dip, box and cool 1000 stems.

Pest and disease control

The most important diseases, pests and disorders affecting rice flower are shown in the accompanying table. The most common and damaging problems are those affecting root systems.

Many of the major problems listed are interrelated. *Phytophthora* or root-knot nematode damage may provide entry for wood rots. Root congested plants or those with insect tunnelling in the stems may predispose plants to entry by fungal rot organisms. The end result is more severe disease and more rapid decline and death of affected plants.

There is a need for more selection and testing of lines suitable for particular areas, and for identification of lines tolerant of *Phytophthora cryptogea* and root-knot nematode (rice flower is tolerant of *P. cinnamomi*). Good quality nursery stock that will not develop congested roots should be planted into nematode free, well drained soils not conducive to phytophthora root rot development.

Pests and diseases of foliage and flowers have the potential to reduce stem yield or quality or cause quarantine problems in the importing country. These should be controlled with a strategic and preventative spray program in the pre-flowering and flowering stages.

Diseases, pests and disorders	Cause
(a) Roots	
Phytophthora root and collar rot	*Phytophthora cryptogea*
Root-knot nematodes	*Meloidogyne* spp.
Root congestion	Plants held for too long in containers before planting
(b) Stems and roots	
Wood rot associated with damage	Fungi such as an unidentified basidiomycete, *Macrophomina phaseolini* and *Phialophora* sp.
Borer damage	Longicorn beetle larvae
(c) Foliage, shoots and flowers	
White blister	The fungus *Albugo tragopogonis*
Shoot dieback	Undetermined, possible insect sucking damage, nutritional disorders or fungal disease
Insect damage	Mealy bug, spittle bug, tip borers, aphids and scale

Harvest, handling and postharvest treatments

Rice flower is usually harvested when 50% of the buds ('rice grains') in the flower head are at full size and not more than 10% have broken (stigmas emerged). The stems at the base of these buds may wilt in flowering stems harvested before this stage of maturity. This harvest 'window' normally lasts only 2–5 days. When correctly harvested, a vase life of more than 10 days can be expected. In some varieties tested, harvesting could be undertaken at an earlier stage, without wilting or loss of vase life. This has the potential to further extend the harvest period.

The time and duration of harvest will depend upon variety and growing location. The bulk of the rice flower crop is harvested in September and October, with small quantities maturing—depending upon location—in August, November and December. Changes in the harvest season can occur from year to year at the same location, possibly due to changes in seasonal temperatures.

A one-cut harvest can be used where flower maturity is uniform within the crop. Cut material is then extensively sorted after harvest. A longer flowering season allows individual stems to be harvested to length as needed.

Cool storage within two hours of harvest is recommended, as is the holding of this commodity at around 2°C throughout the marketing chain. Leaf blackening may occur when the harvested crop is exposed to high ambient temperatures (for example >25°C). The minimum on-farm requirement is for access to a conventional cool store, although fan-forced cool stores are desirable.

Most markets require product to be free of insect pests and diseases. As a precautionary measure, packaging sheds either dip or fumigate export bunches.

Maturity and objective quality standards for rice flower have been developed for the Flower Export Council of Australia, primarily for export. The standards incorporate flower, foliage and stem quality, harvest maturity, uniformity of grading, accuracy in labelling and postharvest cooling. They provide a basis for Australian rice flower growers to meet customer requirements for quality and consistency.

The Japanese market values clean, distinct flower colour (clear whites and non-fading pinks), uniform maturity within the flower head with no 'bypassing' (vegetative shoots) and strong straight stems. Clean and green, high density foliage is used as an indicator of product freshness.

Rice flower can be air dried, preserved in glycerine and other proprietary treatments and responds to uptake dyeing.

Economics of production

The capital investment required, excluding the cost of land, can be high for rice flower production. Around $80,000 could be needed for new equipment on a 5 hectare plantation. Forty thousand dollars should be allocated for buildings and property improvements, including packing shed and fittings, forced air cooling and cold room, irrigation equipment, pumps, dam, a fertiliser injector, windbreaks and fencing. Machinery costs total $40 000, and include a tractor, slasher, spray equipment and a delivery vehicle. Costs can be reduced by purchase of second-hand equipment or seasonal hire, for example of a cool store.

A floral display including rice flower

Cash flow budget for one hectare of rice flower (4000 plants)*, in south-east Queensland.

	Year 1	Year 2	Year 3	Year 4	Year 5
Total number of harvested stems	36000	83600	92000	78400	49000
Variable costs					
rooted cuttings @ $1.50 per plant	6000	600			
site preparation	9100				
sprays, irrigation, fertiliser, fuel	1900	2650	3110	3110	3110
field labour @ $11.00 hour	3450	1340	1030	1030	1030
harvest and post-harvest handling	6120	14210	15640	13330	8330
Total variable costs	26570	18800	19780	17470	12470
Gross income[a]	15840	36780	40480	32400	20090
Annual net return	-10730	17980	20700	14930	7620

[a] The production budget assumes a medium density planting of 4000 plants per hectare. The cumulative mortality is set at 10, 20, 30 50 and 70% in years 1 to 5, respectively. Strip fumigation costs are included in the establishment budget. Per plant yields are set at 10, 25, 30, 35 and 35 stems for years 1 to 5, respectively. Export returns are set at $0.50 per stem, with the domestic sales at $0.20 per stem. The ratio of export to domestic grade stems is assumed to be 80:20 in years 1, 2 and 3 and 70:30 in years 4 and 5. Average yearly returns of $10,700 hectare can be achieved with a continuously rotating planting over a 4-year period.

Cash flow budgets are strongly sensitive to price movements and yield reductions. At high mortality rates it is possible to achieve a return on investment only if a high market price per stem is received. At low market prices major losses are sustained, even when plant survival is excellent. To succeed in the rice flower business, high prices, achieved through quality, innovation and service, along with low plant mortality rates and high yields, are required.

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NB: An extended list of rice flower references is available from GrowSearch Australia, Phone/fax. (07) 3821 3784.

Smokebush

Kevin A. Seaton
Mark G. Webb

Introduction

Smokebush (*Conospermum* species) commonly occurs along highways north of Perth and appears as extensive fields of white to grey woolly flowers, which are said to resemble clouds of smoke. There are 53 species of *Conospermum* occurring throughout Australia, 80% of them found in Western Australia. Smokebush is mainly bush-picked and offers an opportunity for development as a cultivated export wildflower with a diversity of colours (white, grey, pink and blue) and varying flower displays. Cultivated material from trial plots in Perth, Western Australia was test marketed in 1996. The flowers were well received on the local and Japanese markets.

Conospermum species can be propagated vegetatively but some species are often difficult to strike and tissue culture is increasingly being used by propagators. A range of species is available from commercial nurseries. Methods of cultivating these plants are being developed by Agriculture Western Australia with financial support from RIRDC. To date, several commercial stands of smokebush have been established using results from these investigations.

Grey-white flowered smokebush is used mainly as a filler flower, similar to Geraldton wax, but some of the blue forms may be used as feature fillers commanding a higher price. Introduction of new selections with form and colour variation provides an opportunity to compete with established feature filler products such as Gypsophila and statice.

Markets

Over 99% of smokebush entering the market is picked from natural populations.. Flowering stems are available, depending on species, from July to February and are exported to Japan, the USA and Europe.

Stems are sold fresh (e.g. *Conospermum stoechadis*) or preserved and dried (e.g. *C. crassinervium*). Prices are low for the bush-picked product; e.g. 5–10 cents/ stem. It is expected that this situation will change with the introduction of better selections and higher quality cultivated material.

Key statistics

Currently 70,000 stems are exported, 99% from bush picked material

Export prices received range from $1.00 to $1.40 per stem.

Production requirements

Conospermum species occur in 250–900 mm rainfall areas with yearly mean maximum/minimum temperature ranges from 23/13°C to 20/10°C.

They prefer sandy to sand over gravel soils with good drainage and a pH in the range 4.5–5.5 (1:5, $CaCl_2$). Some species appear to be frost tolerant.

Plants require 3–18 ML of water/ hectare/annum, depending on planting density (3300–13200 plants/ha) and potential evaporation. They are best established in spring using drip irrigation. The soil surface needs to be kept moist during establishment.

It is expected that *Conospermum* spp. could be grown in sandy locations in the areas of Australia indicated on the accompanying map.

Varieties

The main *Conospermum* species with potential as cut flowers are *C. caeruleum* (slender smoke), *C. crassinervium* (tassel smoke), *C. eatoniae* (blue smokebush), *C. floribundum* (blue/white smokebush), *C. incurvum* (feather smoke), *C stoechadis* (common smokebush), and *C. triplinervium* (tree smoke). These have a range of flower colours, flowering times and growth habits, as summarised in Table 1.

C. eatoniae is suited to drier regions, while *C. caeruleum* prefers cooler climates. They have the potential to yield more than 50 stems/plant for 2-year-old bushes in cultivation.

C triplinervium is a high yielder, producing strong, 90 cm long stems with panicles of white flowers. These species are currently available commercially in Western Australia.

Agronomy

C. eatoniae requires a weed and disease-free sheltered site with a low nutrient status. Planting is done in beds 3 m apart. For *C. triplinervium* each bed has a single row with 1 m between plants, and for *C. eatoniae* double rows 0.6 m apart and from 0.5 to 1.0 m between plants.. Beds should be mulched to help weed control, reduce soil temperatures in summer and keep the soil surface moist.

Plant should be planted into moist soil and watered regularly during establishment. Irrigation should be applied through drippers to maintain the soil at field capacity. Plants grow best when small amounts of nutrients are supplied regularly

White flowered *C. triplinervium* species

Production of *C. eatoniae* using trellis support system

About the authors

Dr Kevin Seaton has conducted research into the agronomy, management and postharvest treatment of a range of wildflower species. His research focuses on the introduction of new wildflowers for export.

Mr Mark Webb has been involved in the development of new wildflowers for floriculture. He currently manages the Agriculture Western Australia wildflower selection and breeding research program.

See *Key contacts* for authors' addresses.

Table 1. Cut flower characteristics of *Conospermum* species from surveys of several naturally occurring and cultivated populations.

Species	Flower colour	Average stem production per planta	Range of stem lengths (cm)	Growth habit	Flowering time
C. caeruleum	blue	medium	50–65	spreading	July–Oct.
C. crassinervium	white	low	80–90	upright	Dec.–Feb.
C. eatoniae	blue	high	50–80	upright	July–Sept.
C. floribundum	blue/white	high	7–15	upright	July–Oct.
C. incurvum	white	medium	20–35	upright	Aug.–Oct.
C. stoechadis	grey/white	high	50–80	spreading	July–Oct.
C. triplinervium	white	high	50–90	upright	June–Nov.

a Low < 25 stems, medium 25–50, and high > 50 stems per plant.

by fertigation. In a sandy soil, stem production was maximised with the application of 40 mg/plant/day of nitrogen and potassium and 5 mg/plant/day of phosphorous plus trace elements.

C. eatoniae should be protected from wind damage and supported in the first year of growth by one layer of trellising (150 mm × 150 mm mesh) (Cyclone,) located at 200 mm above the ground, similar to that used for carnations. Pre- and post-planting weed control is needed.

Plants established in spring will have harvestable stems by the next flowering season with yields increasing in subsequent seasons. Stems should be pruned immediately after harvest.

Pest and disease control

Young transplants are susceptible to aphids, and moth larvae can cause loss of stems during flowering.

Bunched smokebush arrived at export markets in Japan

Harvest and handling

Harvesting should begin as soon as flowers appear and, to prevent loss of quality, should cease before flowers loose freshness. Flowers must be picked in the cool of the day and the stems placed in water as they easily dehydrate. No special solution treatment after harvest is needed and vase life of these species is at least 10–12 days with proper postharvest handling. It is easier to grade and bunch in the packing shed than in the field. Care needs to be taken to ensure that bunches are uniform. Bunches of 5 stems are suitable for *C. eatoniae*, and 10 stems for *C. caeruleum*. For other species, the stem number per bunch varies between 10 and 15. Bunches of *C. eatoniae* are packed in perforated sleeves to keep stems from tangling, and allow bunches to be packed more tightly. Flowers can be treated for insects before export by aerosol fumigation with Insectigas D,/Pestigas P,. Bunches should be cooled to 2°C before export shipment.

Economics of production

There are no data available on the economics of producing these wildflowers. However, they can be produced using the existing infrastructure for growing other wildflowers provided drip irrigation and fertigation is possible. In 1996, prices of $1.00–$1.40 per stem c.i.f. were received for test market shipments of *C. eatoniae* to Japan.

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Key messages

- Large range of flower types
- Vibrant blue flowered species
- High production wildflower

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Stirlingia

Aileen Reid

Introduction

Stirlingia latifolia is a major bush-picked export crop. More than 2.9 million stems with a value of about $348,000 are picked each year. While the species is relatively abundant in its natural growing area, urban encroachment is steadily reducing the extent of its habitat. This, together with considerable seasonal variation in quality, and low marketable yields, is contributing to increasing interest in cultivating this crop.

Markets and marketing issues

Japan, the USA, Europe and Taiwan are the major markets. Demand is steady, but most exporters agree that quality is a major constraint. The quality of stirlingia harvested from the bush varies from year to year, and only one year in four yields good product. The proportion of marketable blooms from a given stand averages only 15%.

Traditionally, stirlingia has been sold when in fruit as a processed product, either in its natural colours or dip-dyed. However, it can also be sold in bud or in flower, either fresh, or dipped in dye or paint. Most fresh product is currently sold processed. The proportion of stems sold fresh and unprocessed could be expanded by the use of selections with different bud colours.

Production requirements

In its natural state, stirlingia occurs in Western Australia on well drained and nutrient-depleted sands extending from Kalbarri in the north to Albany in the south-east. A frost free site with no waterlogging is essential. Soil should be slightly acidic with a pH of 5.0–6.0. Avoid alkaline soils.

Stirlingia is a member of the family Proteaceae and so prefers low levels of phosphorus. Where land has previously been used for farming or other forms of horticulture, a soil test for residual phosphorus is necessary to ensure that toxic levels of this element are not present. No standards exist for *Stirlingia* but levels above 30 ppm (used for other proteaceous crops) could be expected to cause problems.

Soil should also be tested for the presence of Phytophthora and/or nematodes. If Phytophthora is present, consider another site. Satisfactory treatments can be applied for nematodes.

Varieties/selections

Stirlingia plants are usually supplied as tissue-cultured plantlets, although cuttings from cultivated plants do strike reasonably well. Only one standard form is currently available with potential to exploit other forms which have variation in bud colour (dark red through to orange and lemon, either as single or mixed colours) for the fresh market product.

Agronomy

Tissue-cultured plantlets are best planted in autumn. They then establish over winter and flower in the first spring. Spring plantings may also be satisfactory where well controlled irrigation systems, able to respond to sudden changes in weather, are installed. In sandy soils, once-a-day watering should be sufficient in spring and autumn, while irrigation two to three times a day may be necessary in hot weather, particularly in the first year. Low-tension tensiometers are proving quite reliable in sandy soils.

If fresh seed is available, good germination rates can be obtained by using the smoke treatment (as developed by Kings Park and Botanic Gardens) as an alternative method of propagation.

In the first year, plants tend to send up one flowering stem which is often unmarketable due to the thick stem which overpowers the inflorescence. In addition, because the plant consists only of one fan, and a large flowering stem, it is unbalanced and often falls over. Pruning before the first flowering has not proven useful in overcoming this problem. Trials at Medina Research Station indicate that pruning back to 25–50% of the foliage height after the first flowering provides a much better response. Almost every leaf axil will shoot, with the result that the following crop should easily achieve 5–8 stems per plant. Pruning back to ground level in the first year has proven fatal, possibly since the carbohydrate reserves of the young plant are too low to permit resprouting. Anecdotal evidence from other growers suggests that pruning back to ground level in subsequent years should not pose a problem.

A natural stand of *Stirlingia latifolia* at late bud

A bunch of stirlingia picked in the traditional fruiting stage

Before planting apply a base dressing of mixed trace elements and lime if necessary. Plants should ideally be fertilised with low rates of NPK fertiliser via the irrigation water (75 ppm nitrogen, 15 ppm phosphorus, 50 ppm potassium).

Pest and disease control

Stirlingia naturally grows in nutrient-poor, well-drained sands. Growers should therefore be aware that excess fertiliser salts or poor drainage may cause a high risk of root damage and subsequent root rot. Routine treatments with phosphorous acid (Fosject®) as a foliar spray are recommended for the prevention of Phytophthora and Pythium root rots but are no match for poor soil conditions in controlling these diseases.

About the author

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Colour variation in stirlingia at the bud stage. This is also a marketable product.

Key statistics

Stems of stirlingia picked from the bush from 1992 to 1996.

Year	Number of stems
1992	1,681,960
1993	2,999,310
1994	3,019,459
1995	2,385,625
1996	2,500,000 est.

Alternaria leaf spot has been observed on cultivated plants at the times of the year when rain occurs. Control is difficult but sprays of Rovral® or Mancozeb' should help. At flowering time, Botrytis can cause flower and fruit abortion. Use a rotation of chemicals such as Rovral®, Mancozeb' and Octave® to prevent the build-up of resistance.

Young shoot growth may be susceptible to aphids and thrips. Use synthetic pyrethroids such as Mavrik® to control these pests.

Harvest, handling and postharvest treatments

The criteria for determining stem quality (Table 1) in *S. latifolia* have some specific requirements in terms of bobble positioning. It is important for the shape of the inflorescence to be clearly delineated. Thus, the bobble at the very tip of the inflorescence must be present and also those around the perimeter of the inflorescence. Since these bobbles are exposed, they are especially prone to desiccation by winds and frost damage and regularly fall off in the wild. In cultivation, this problem should largely be solved with the use of windbreaks.

There do not appear to be any major postharvest problems with fresh stirlingia. The use of a biocide such as chlorine or 8-hydroxy-quinoline sulphate in the holding buckets may be beneficial.

It is more usual for the exporter to process the product. This way, dyeing is done to fill specific orders. Dyeing is usually by immersion rather than uptake. Product which is to be dried or dyed does not need to be placed into water, but simply packed for transport to the exporter.

Economics of production and processing

This plant lends itself to high-density plantings which are necessary to for an economic return. One scheme is to use 6-row beds with rows 0.5 m apart within the bed, plants 0.5 m apart within a row and 3 m between beds. Such plantings contain just over 22,500 plants/ha . Assuming a maximum yield of 15 stem/plant, the return will be $40,000/ha at $0.12 per stem. Allowing for a fairly heavy spraying program, after operating costs, this reduces to about $8300/ha. It may be possible to harvest mechanically but this has not been tested.

Examples of poor seed set in stirlingia. These blooms are unmarketable.

Table 1. Criteria for *Stirlingia latifolia* stem quality.

1.	The stem must be picked when the ' bobbles' are silvery, i.e. fully mature. If the stems are picked too early, dye is not taken up and the ovaries are still visible as black dots in the centre of the bobble.
2.	' Bobbles' must be present on all key terminal positions, i.e. the presence of these determines the inflorescence shape.
3.	There must be a good number of ' bobbles' and they must be distributed evenly so they are visible individually.
4.	Branch angles should not be too wide.
5.	Stem length should be greater than 60 cm and in proportion to the length of the inflorescence.
6.	' Bobbles' must be full, i..e at least 6 fruits should be present, otherwise the clusters are too small or lopsided.

Key messages

- Stirlingia from the bush is in diminishing supply.
- High densities are needed for economic returns.
- Expand markets using different colour forms.

The major cause of rejection of inflorescences by pickers or exporters in bush-picked material is deficiencies in cluster numbers or their positioning. At least 60 cm stem length is required. Growers should also take care to harvest the stems at the required degree of maturity (see Table 1).

Exporters pay a premium of about $1.00 per bunch if the product is already processed.

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Thryptomene

D.V. Beardsell
A.T. Slater

Introduction

There are various genera in the family Myrtaceae which have stems with numerous attractive flowers borne in the leaf axils. Genera such as *Thryptomene*, *Micromyrtus*, *Scholtzia*, *Corynanthera*, *Malleostemon*, *Astartea*, *Baeckea* and several undescribed but related genera have been used as both landscape plants and cut flowers.

The largest commercial industry is based on *Thryptomene calycina*, commonly known as Grampians thryptomene or Victorian laceflower. The industry is almost entirely based near the Grampians Range in western Victoria, with small plantings elsewhere in Victoria, and in New South Wales, South Australia, Queensland, New Zealand and California. Production has been increasing by approximately 10% per year due to continued expansion of plantings.

The best material of Grampians thryptomene represents a world-class filler flower which can greatly enhance feature flowers in arrangements. The opportunities for this crop are many, since the industry in Victoria has a virtual monopoly over both world production and germplasm. The limited production in California, which is based on inferior cultivars, does not compete with Australian production because flowering in the USA is from November to February. Much of the Victorian production is, however, a second-class product because of limited use of elite cultivars, poor husbandry, poor postharvest handling and inadequate marketing. The industry is slowly developing better postharvest facilities, and one major grower has adopted quality standards.

Production of export quality Grampians thryptomene requires considerable skills in interpretation of seasonal cultural requirements, including supplementary irrigation, pest and disease management and postharvest handling. There are also opportunities for growing other species of *Thryptomene* including *T. australis*, *T. denticulata*, *T. baeckeacea*, *T. stenophylla* and *T. saxicola* from Western Australia, *T. elliottii* from Kangaroo Island, *T. micrantha* from Victoria and Tasmania, *T. parviflora* and *T. hexandra* from Queensland, and *T. maisoneuvei* from central Australia. These, except for *T. elliottii*, produce flowering stems that are inferior to those of *T. calycina* (Grampians thryptomene). The following discussion thus concentrates on Grampians thryptomene.

Markets and marketing

Most of the annual production (10 million flowering stems) of Grampians thryptomene is exported. Approximately 3 million stems are sold annually in the domestic market in the eastern States. It is the largest flower export from Victoria, with 250,000–300,000 kg sold annually to markets on the west coast of the USA. Although Asian markets like small white flowers, the supply of poor quality product has limited its acceptance in the Japanese market. Early in the 1996 season, prices were high and this led to an oversupply of inferior flowers on the US, market causing a crash in the price. Such uncoordinated marketing almost ruined the reputation of thryptomene, although prices improved later in the season.

The wholesale price of Grampians thryptomene varies from $1.40 to $1.60 a bunch with between $0.90 and $1.20 returned at the farm gate. Export prices at the start of the 1997 season were $A3.20 a bunch for quality product, with the grower receiving $1.80 a bunch.

In Victoria and California, Grampians thryptomene is used in a similar role to gypsophila: as a filler in floral arrangements complementing other major flowers such as roses. Flowering stems suitable for marketing are available from late May (with many flowers in bud on the stems) until early September. Peak flowering occurs in Victoria in July–August, although this varies with both the cultivar and the season. While the quality of flowers has improved dramatically in recent years, flower quality can be poor in the season after a very dry summer–autumn. Attractive stems with unopened flowers can be picked in May and June, but stem quality falls quickly in September as spent flowers and fruits start to abscise and soft new season's growth occurs. Late season flowers are more prone to fungal rots during transport, possibly due to the increase in nectar production or because of the soft new growth of stems. A quality assurance program is needed to define the standards for this crop. This is currently being developed by a major grower wanting to supply consistently high quality produce to the export market.

There has been little attempt to properly market *Thryptomene calycina*, and it is still sold as 'thryptomene' (in Australia), 'Grampians thryptomene' (in Victoria) and 'calycina' (in California). It needs to be actively promoted under one name, 'Victorian laceflower'. The adoption of quality assurance and market promotion should alter the image of this crop and increase its market value.

The delightful *T. calycina* 'Coral Lace' showing the dense flowering and pink sepals

Thryptomene calycina 'Ivory Lace'

About the authors

Dr David Beardsell is Industry Manager Ornamentals in Agriculture Victoria and spent six years working on the development of the Grampians thryptomene industry.

Tony Slater is a research scientist with Agriculture Victoria and has spent the last eight years developing new ornamental crops.

See *Key contacts* for authors' addresses.

The establishment costs for a 1 ha plantation of Grampians thryptomene is as follows:

Plants/ha	3,300
Plant costs	$2640
Irrigation[a]	$2800
Basal fertiliser	$200
Buckets	$300
Weed mat[a]	$4000
Total	$9940.00

[a] Not all plantations use irrigation and weed mat.

Production requirements

In Victoria, *T. calycina* is grown mostly on sandy well-drained soil, although it is also grown on heavy soils in the Black Range.

Nothing is known about the cultivation of the arid zone *Thryptomene* species, although they may be difficult to grow in areas with more than 300 mm annual rainfall and in heavy soils. Most of the non-arid land species are native to heathlands and are also difficult to grow outside their natural habitats. All species cultivated so far need well-drained soils free of root rotting pathogens such as *Phytophthora cinnamomi*. The only species known to be hardy is *T. saxicola*.

The arid zone *Thryptomene* species, including those in Western Australia, occur in sandy soils where the rainfall is only 150–250 mm per year. In south-west Western Australia, *T. australis* and *T. saxicola* occur in soil pockets on granite outcrops. *Thryptomene micrantha*, *T. oligandra* and *T. parviflora* grow in moist sandy soils. The climate suitable for growing most species is temperate, although inland species would require sunny, hot climates for optimal growth and survival.

Varieties

Development of superior cultivars which are clonally propagated is a major requirement for cut-flower production. The natural variability of Grampians thryptomene has enabled selection of plants with large flowers, uniform flowering, early and late flowering, short and long flowering laterals, and plants with pink sepals, and anthocyanin-free flowers. The two main superior varieties are 'Ivory Lace' and 'Coral Lace" which were selected at the Institute for Horticultural Development, Knoxfield. Limited numbers of these are available from several nurseries and plant propagators in Victoria. The selection of early- and late-flowering clones of Grampians thryptomene will extend the harvest period to April–October. Superior clones can also be used in breeding programs. Interspecific hybrids can be produced between some members of Western Australian *Thryptomene*, but reproductive barriers limit hybridisation between these and members of the genus from eastern Australia. Breeding programs should aim to improve both flowering characteristics and resistance to diseases such as *Phytophthora cinnamomi*.

Agronomy

Sites will need to be free draining, and frost hollows should be avoided. For cut-flower production, rows of Grampians thryptomene should contain plants spaced at 0.5–1.5 m. Hilling-up should be done in heavier soils, and should follow land contours. Plants can be planted out as tubestock in autumn and watered in; subsequent irrigation depends on seasonal conditions. Tree guards may help early establishment. Early losses may occur from root diseases, corellas, cockatoos and rabbits.

While little is known about the nutritional requirements of *Thryptomene* and related genera, they are often found growing in soils of low fertility. Unlike some Australian plants they do not appear to be sensitive to high levels of phosphorus in potting mixtures. The only fertilisation required would be to replace nutrients removed in harvested flowers. This should be applied after flowering to enhance new shoot growth which provides the next season's flowers. Excessive fertilisation can result in soft shoot growth during spring which reduces the quality of flowering stems. Without irrigation in the Grampians, shoot extension is not great enough to allow harvesting of all stems on a bush each year. Growers selectively harvest the longer stems and leave the short new leads to ensure a yearly harvest from individual plants.

Species from low to very low rainfall regions are very slow-growing and supplementary watering to enhance shoot growth may ensure adequate stem length and flower production. The flowers of most of these species occur in the axils of leaves, and thus promotion of extension growth should produce more flowers. Supplementary watering in dry seasons also reduces flower and leaf abscission, thus enhancing flower quality at harvest time. Both drip and microjet irrigation have been used successfully in plantations of Grampians thryptomene in Victoria. Water used from dams should be chlorinated or chloro-brominated at 3 ppm for 4 minutes to prevent the spread of *Phytophthora cinnamomi.*

Depending on the size of planting stock and after-care, flowering stems can be harvested in the second or third season. Although harvesting of Grampians thryptomene occurs only from May to September, weed control, irrigation and maintenance of facilities make growing high quality flowers a full-time operation.

Flowers can be damaged by severe frosts (below –3°C). Frosts of –5°C will kill bushes of Grampians thryptomene and *Thryptomene saxicola*; the bark splitting to ground level. Inland species may have greater frost tolerance.

Most of the Western Australian species are easy to propagate

An estimate follows of the expected gross margin returns for a 1 ha plot of Grampians thryptomene. It is based on production of average quality product.

	Assumptions	year 1	year 2	year 3	year 4
Plant life	10 yrs				
No stem/plant		0	10	20	40
No plants/ha	3,300				
No stems/bunch	10				
Return per stem	export grade $0.18				
Bunches/plant		0	1	2	4
Bunches/ha		0	3300	6600	13200
Stems/ha		0	33000	66000	132000
Gross return/ha		0	5940	11880	23760
Variable costs					
Farm maintenance					
Labour @ $12/hour planting	60 plants/hour	660			
Labour @ $12/hour maintenance	150 hours	1800	1800	1800	1800
Fertiliser		780	780	780	780
Chemicals		200	200	200	200
Operating expenses		2000	2000	2000	2000
Subtotal		**5440**	**4780**	**4780**	**4780**
Harvest/postharvest					
Labour @ $12/hour harvesting	60 bunches/hour	0	660	1320	2640
Labour @ $12/hour grading	80 bunches/hour	0	495	990	1980
Counting, dipping, boxing	$0.30 per bunch	0	990	1980	3960
Boxes @ $4.50 each	30 bunches per box	0	495	990	1980
Freight @ $2.50/box		0	275	550	1100
Subtotal		**0**	**2915**	**5830**	**11660**
Total variable costs		**5440**	**7695**	**10610**	**16440**
Gross margin		**–5440**	**–1755**	**1270**	**7320**

from cuttings. Little is known about propagation of the central and South Australian species, although *T. maisoneuvei* has proven difficult to strike (W. Tregea, pers. comm.). The eastern Australian species, *T. calycina*, *T. micrantha* and *T. parviflora*, can be propagated from tip cuttings of semi-firm shoots which are not in flower, but which may have flower buds. The strike rate varies enormously during the season, with the highest rates achieved in early and late summer. Rooting is improved by treatment with 2000–4000 ppm indolebutyric acid.

No information is available on the use of growth regulators on any of these plants. Cyclocel (CCC)®, Atrinal® and Bonzi® need to be tested, as they may be effective in inhibiting the undesirable soft new growth which occurs on many species towards the end of the flowering season.

Key messages

Victorian laceflower has the potential to be a world class filler flower if high quality flowering stems are marketed and promoted. This market will be undermined if poor quality flowering stems continue to be produced.

Most species of *Thryptomene* are not well known in cultivation and much work needs to be done to develop them into high quality, profitable crops.

Pests and diseases

A number of pests and diseases have been found on Grampians thryptomene (Beardsell 1992). The main threat to this species in cultivation, both as a cut flower plant and a landscape plant, is its extreme sensitivity to the root-rotting pathogen *Phytophthora cinnamomi*. It can, however, be readily grafted onto the more adaptable *T. saxicola* which has some resistance to Phytophthora (Meyers 1993; Beardsell 1993a). Tip dieback of branches also occurs from an interaction of the pathogens *Botrytis* sp., *Pestalotiopsis* sp. and *Phoma* sp., which can be controlled by application of Mancozeb, (Beardsell 1992). Large losses of cuttings have also occurred from the soil-borne fungus *Cylindrocladium scoparium*. Cuttings and young plants are also sensitive to dampening-off fungi from the genus *Pythium*. This disease affects only plants less than 10 cm high. To remove the threat from these fungal diseases, all plantations should be regarded as quarantine areas, with limited access to vehicles, machinery and persons from outside. All materials and equipment brought into plantations should be disinfected. Troughs containing a disinfectant should be located at the entrance of farms.

Webbing caterpillars (*Strepsicrates ejectana* (Walker)) feed on the foliage and borers can ring-bark stems. Thrips feed on the nectar and pollen produced by the flowers, and if exporting, these need to be controlled by fumigation or by dipping stems in an insecticide, otherwise shipments may be rejected by overseas quarantine authorities.

Harvesting, handling and postharvest treatment

Harvesting is usually done with secateurs and stems are tied into bunches for storage and transport. Limited postharvest handling treatments are used, but the flowering stems have a shelf life of up to 14 days if the stems are quickly placed in a cool store in buckets containing a flower preserving solution or covered with moistened hessian covers. Covering with dry hessian does not extend shelf life. One of the main causes of poor quality of flowering stems of Grampians thryptomene and related species in florist shops is poor handling. After harvest the flowers should be cooled, placed in a preserving solution and marketed as soon as possible. Cooling to approximately 1°C is very important before and during all stages after harvest, including transport (Beardsell 1988). Rehydration of flower stems while they are cooling after storage and transport improves quality and vase life. This involves immersion of the lower parts of the stems in a solution containing a germicide and an acid (0.5 g/L citric acid) or commercial preservative for 24 hours.

Vase life varies between and within species. One clone of Grampians thryptomene has a vase life of nearly 14 days at 20°C whereas most clones last only 7 days. However, these times can be improved dramatically by appropriate postharvest handling treatments such as using flower preservatives, recutting stems and regularly changing vase water.

Stems of Grampians thryptomene can be stored for several weeks if treated with a fungicide and packed in boxes lined with moist newsprint. If they are properly rehydrated, there will only be a small reduction in subsequent vase life. This means that boxes of Grampians thryptomene could be sea freighted if treated correctly.

Economics of Production

A farm growing quality flowering stems of Grampians thryptomene would need a small tractor or all terrain vehicle (ATV). The vehicle should be outfitted to spray the crop with insecticides and fungicides. Weeds should be controlled by mowing, herbicides or cultivation. The vehicle should have a trailer for harvesting and bringing the flowers back to the shed in buckets for grading and storage. A shed is required for sorting, grading and processing the flowers. Scales, trimming and banding equipment will be required. A cool room is required to cool the flowers as soon as they are processed, and access to reliable refrigerated transport is needed to take flowers to markets, wholesalers or exporters. Access to a good supply of quality water is important and water disinfestation equipment may be required if dam water is used.

A much better return for Grampians thryptomene will be attained only by developing improved varieties, better cultural practices, better postharvest handling, reduced production of poor quality flowers, and better market promotion and product imaging.

Future developments

Several species including *T. ericaea*, *T. elliottii*, *T. micrantha* and *T. parviflora*, and related genera such as *Baeckea*, *Astartea*, *Micromyrtus* and *Scholtzia* could be potential cut-flower crops if research is done on selection of good varieties, propagation methods, cultivation and postharvest technologies. More infomation is needed on the arid-zone species before they could be introduced into cultivation in dry regions.

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The ***New Rural Industries***

A Handbook for Farmers and Investors

Edited by K.W. Hyde

This handbook is a comprehensive introduction to 'The New Rural Industries' for farmers and investors, and for bank managers, farm advisers, students and others with an interest in rural Australia. It addresses the most frequently asked questions about the market prospects, production–processing requirements, the costs of production and the prospective returns for 94 of Australia's smaller or potential new animal, aquaculture and plant industries.

'The New Rural Industries' is a factual text which gives a 'warts and all' assessment of the strengths, weaknesses, opportunities and threats for each industry. It also provides an overview of the key success factors in the development of new industries, how to initiate your own market research and where to get advice or additional information.

Each chapter has been researched and written by highly regarded experts in each industry or product. Ten chapters on the 'new' aquaculture industries have been cosponsored by the Fisheries Research and Development Corporation. Each chapter has been reviewed by industry practitioners, researchers and by a RIRDC–FRDC editorial review panel.

The production of 'The New Rural Industries' was planned, managed and edited for the Rural Industries Research and Development Corporation by Mr Keith Hyde. Keith Hyde has played a key role in the development of new rural industries in Australia for over 30 years as inaugural Managing Director of RIRDC, a member of the former Australian Special Rural Research Council, Assistant Director of the Bureau of Rural Sciences and Senior Agronomist in the Northern Territory.

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