



Wattle Seed Workshop Proceedings

12 March 2002, Canberra

**Proceedings of a Workshop to Assess
Prospects and Develop R&D Priorities
for a Wattle Seed Industry**

edited by
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– Agtrans Research

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Foreword

Wattle seed (*Acacia* spp.) has been used as a food source by Australian Aboriginal people for thousands of years. More recently, there has been a small but increasing demand for wattle seed as part of the commercial bush food market. Further, *Acacia* spp. are often used in planting programs aimed at ameliorating land degradation. With this background it has been suggested that the opportunity for broadscale wattle seed production and use of wattle seed in mainstream food production industries such as bread and biscuit making as well as in animal feed industries be investigated as a commercial output of future plantings of perennial species to combat rising water tables and dryland salinity.

This workshop was funded by— The Joint Venture Agroforestry Program of the Rural Industries Research & Development Corporation, Land & Water Australia, Forest and Wood Products Research and Development Corporation and the Murray Darling Basin Commission.

This report, a new addition to RIRDC's diverse range of over 900 research publications, forms part of our Joint Venture Agroforestry Program, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirc.gov.au/reports/Index.htm
- purchases at www.rirc.gov.au/eshop

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Acronyms and Abbreviations

ABARE	Australian Bureau of Agriculture and Resource Economics
AFFA	Agriculture, Fisheries and Forestry Australia
AGB	Above Ground Biomass
AGO	Australian Greenhouse Office
ANPI	Australian Native Produce Industries
CRC	Cooperative Research Centre
DMD	Dry Matter Digestibility
FAO	Food and Agriculture Organisation
FWPRDC	Forest and Wood Products Research & Development Corporation
GI	Glycaemic Index
GRDC	Grains Research and Development Corporation
GST	Goods and Services Tax
JVAP	Joint Venture Agroforestry Program
LWA	Land & Water Australia
MDBC	Murray Darling Basin Commission
NGO	Non-Government Organisation
NHT	Natural Heritage Trust
NSP	Non-Starch Polysaccharide
OMD	Organic Matter Digestibility
PD	Protein Digestibility
R&D	Research and Development
RFLP	Restriction Fragment Length Polymorphism
RIRDC	Rural Industries Research and Development Corporation
USDA	United States Department of Agriculture

Editorial Note

The Editors have taken some licence in their summarising of the various discussions held at the workshop. There were some comments that were inaudible on the transcript tapes and while every effort was made to identify speakers and their contributions, a few gaps are still likely to be evident.

A draft of these proceedings was sent to all of the workshop participants and several comments were received and changes made. However, any remaining omissions, errors or misinterpretations remain the responsibility of the editors.

While there were only nine papers actually presented at the workshop, a tenth paper on harvesting systems by Harry Harris is included as it was submitted to the workshop, however no presentation was able to be made. It is felt that this paper provides a valuable contribution to the outcomes of the workshop and is therefore included in these proceedings along with the other presented papers.

Executive Summary

The purpose of the workshop was to gather relevant parties together to further discuss the issues raised in earlier reports, and gain some consensus on the next steps necessary to assess the potential for a broadscale wattle seed industry.

The specific objectives of the workshop were to:

- Consider existing knowledge on production, processing and marketing factors in developing a wattle seed industry
- Compare a broadscale wattle seed industry to other opportunities for commercial solutions to salinity and how it relates to the “Flora Search” initiative currently being developed
- Determine future activities, including research and development (R&D), necessary for the large scale commercialisation of a wattle seed industry

A key principle driving the workshop was its focus on revegetation of large tracts of land with a broadscale wattle seed industry, not on a small industry with niche markets.

The papers presented covered broad considerations such as factors driving economic potential and industry opportunities. Other papers focused on genetics; health, nutrition and food processing markets; prospects for harvesting systems; and the implications of using *Acacias* for lowering water tables.

General discussion was wide ranging until the workshop broke into four groups, each addressing one of the following four topics:

1. Wattle Seed in the Context of Other Woody Perennial Crops
2. Market Prospects
3. Production Systems (1 million tonne market)
4. Production Systems (100,000 tonne market)

As a result of these discussion groups and a final plenary session the following conclusions and recommendations were developed:

1. There is not sufficient information currently available to make conclusions about the potential for a broadscale wattle seed or *Acacia* industry. The most limiting factor is knowledge about the nature or size of the markets that wattle seed may be able to supply.
2. Large-scale agroforestry industries are of most interest to the Joint Venture Agroforestry Program (JVAP). Until the market prospects for wattle seed are more conclusively addressed, it is difficult to assess whether a wattle seed industry could grow to a broadscale industry.
3. The prospects for a broadscale wattle seed industry need to be assessed further before a decision to support R&D funding from JVAP for developing a wattle seed industry is made. In particular:
 - (a) a balance needs to be developed between developing a wattle seed industry per se, developing an “*Acacia*” industry where wattle seed is viewed as an opportunistic by-product, and other commercial prospects for non-*Acacia* perennial species that address sustainability issues.
 - (b) a decision will need to be made by the Rural Industries R&D Corporation (RIRDC) as to whether JVAP, or the sub-program based on bush foods is the most appropriate funding source for R&D.
4. To assist with these decisions, and to further the development of a wattle seed industry, it is recommended that further R&D activity should be undertaken in phases.

5. The first phase should consist of the following research activities:
 - (a) An urgent consideration should be a marketing study that establishes current and future demand for certain food ingredients, including community health needs and diet preferences. A part of this would be the size and value of particular markets that could potentially be serviced by wattle seed eg mung beans, chickpeas etc. Such a study should include not only products from the seed, but also other parts of the tree such as gum exuded from the trunk, the seed pods and the leaves. Both human and animal nutrition markets should be considered.
 - (b) At the same time, an initial scientific analysis of the nutritional and functional constituents of selected species should be undertaken to determine which of the potential markets identified can be serviced by wattle seed or other *Acacia* products.
 - (c) A review of the legislative and regulatory aspects of developing food ingredients will also be essential as part of this first phase of research.
 - (d) In keeping with an integrated systems approach, desk-top research should continue on the nature and economics of potential production systems. Variables to be considered would include establishment, layout, density, plant shape, harvesting mechanism, fertiliser and pest control.
6. Following the completion of these Phase 1 research activities, a decision should be made as to whether further industry development of any type is feasible. If it is determined there is some potential, a decision should be made as to the potential market or markets to be targeted, and the potential size and likely value of these markets. This will determine the nature of any further research, and whether that research is appropriately funded through JVAP or through some other sub-program. It is recommended that breeding or field trials would be delayed until the Phase 1 studies have been completed, and potential target markets have been identified.
7. If appropriate, once the target market(s) has been determined, and if the overall prospects for market penetration and commercial profitability appear favourable, a systems based research program focusing on species selection and breeding for nutritional and growth characteristics should be undertaken. Selection should consider not only the required nutritional characteristics, but also the desired tree shape and water use characteristics. This breeding program should include field trials.
8. Once it has been determined what tree shape is possible within an envisaged production system, a mechanical harvester and planting system should be developed that maximises cost efficiencies, as well as sustainability benefits. It may be preferable to design the harvester in conjunction with Step 7 above.

1. Introduction

1.1 Background to the Workshop

Wattle seed (*Acacia* spp.) has been used as a food source by Australian Aboriginal people for thousands of years. More recently, there has been a small but increasing demand for wattle seed as part of the commercial bush food market. Further, *Acacia* spp. are often used in planting programs aimed at ameliorating land degradation. With this background it has been suggested that the opportunity for broadscale wattle seed production and use of wattle seed in mainstream food production industries such as bread and biscuit making as well as in animal feed industries be investigated as a commercial output of future plantings of perennial species to combat rising water tables and dryland salinity.

Recent interest in wattle seed includes a report commissioned by RIRDC titled “Wattle Seed Production in Low Rainfall Areas” (Simpson and Chudleigh, 2001). The aims of that report were to:

1. Investigate the potential for broadacre wattle seed production in the medium to low rainfall areas of southern Australia,
2. Assess the implications for resource sustainability, and
3. Determine the potential for use of wattle seed as a substitute for wheat in bread making.

This was followed by a report by Graeme Olsen of Olsen & Vickery (unpublished) titled “Can we build a large-scale wattle seed industry?” The purposes of that review were to:

1. Examine the potential for wattle seed to become a large-scale agricultural crop in the low to medium rainfall zone of southern Australia.
2. Discuss crop development pathways, and farming systems within which wattle seed could be grown.
3. Identify the key issues to resolve.
4. Suggest a mechanism for research and development.

In addition, there had been recent commercial interest in developing a broadscale wattle seed industry from a group called “Wattle Alliance Pty Ltd”.

1.2 Workshop Objectives

The purpose of the workshop was to gather relevant parties together to further discuss the issues raised in the above reports, and gain some consensus on the next steps necessary to assess the potential for a broadscale wattle seed industry.

The specific objectives of the workshop were to:

- Consider existing knowledge on production, processing and marketing factors in developing a wattle seed industry
- Compare a broadscale wattle seed industry to other opportunities for commercial solutions to salinity and how it relates to the “Flora Search” initiative¹ currently being developed
- Determine future activities, including R&D, necessary for the large scale commercialisation of a wattle seed industry

¹ A project supported by the JVAP, Murray Darling Basin Commission and the Cooperative Research Centre for Plant Based Management of Salinity. This project will systematically search through Australia native species to identify those with potentially useful products suitable for cultivation.

1.3 Opening Address

The workshop was opened by Roslyn Prinsley, General Manager of Research for RIRDC, and leader of JVAP. The opening address sought to set the context for the days discussion in terms of the JVAP's activities and priorities, and further reinforce the desired outcomes for the day.

JVAP was established in 1993 as a collaborative undertaking of RIRDC, Land & Water Australia (LWA) and the Forest and Wood Products Research and Development Corporation (FWPRDC). Since 1993 additional funding has also been received from Agriculture, Fisheries and Forestry Australia (AFFA), the Natural Heritage Trust (NHT), the Murray Darling Basin Commission (MDBC), the Grains R&D Corporation (GRDC) and the Australian Greenhouse Office (AGO). The Program's current expenditure is around \$3 million per annum.

The role of JVAP is to coordinate, manage and communicate R&D, particularly development of new tree based farming systems and industries.

It is recognised that trees are definitely part of the answer to solving salinity, biodiversity, greenhouse and other environmental problems and that strategically located tree planting can help to address these problems.

Some conservative estimates say that twenty percent of the southern wheatbelt needs revegetating to combat salinity, although others claim this figure is as high as eighty percent. If it is assumed that the southern wheat belt is 100 million hectares, and that tree plantation establishment costs are around \$1000 per hectare, then this results in a tree establishment bill of \$20 billion which government subsidies can not support. Therefore it becomes evident that commercial tree crops are needed to pay for at least part of that revegetation.

There is also the need for diversification of industries in the low to medium rainfall areas and it is felt there are currently only few commercial industries that can be used as a basis for this commercialisation.

JVAP is investing in scanning and assessing various tree products, for their economic viability in the low to medium rainfall areas.

JVAP currently has a project considering regional scale economics and the viability of production systems for a range of products. Factors such as the size of market, size of processing plant, raw materials, economic transport distances and production costs are all being considered.

One of the objectives of this workshop is to look at wattle seed as an industry in the context of other potential industries – is it going to work? And if it is going to work, what is required to make it work?

Another point to keep in mind is that the JVAP focus is not on niche products or small markets – rather on opportunities which have the potential to drive the revegetation of 100 million hectares. Unfortunately JVAP can not afford to spend money on many very small industries. Therefore if it is decided that there is no potential for a broadscale industry, then further consideration of a wattle seed industry would shift to RIRDC's bushfoods program which addresses the development of niche products.

1.4 The Workshop Process

A copy of the Workshop Program can be found in Appendix 1. The workshop commenced with the brief address by Dr Roslyn Prinsley. This opening address set the context for the day's discussions, in terms of JVAP's scope, and the role that a wattle seed industry would need to fulfil.

The opening address was followed by the presentation of a series of invited papers from a total of nine speakers. These papers covered a range of issues relating to a potential broadacre wattle seed industry, from the genetics of the seed through to high level processing and markets, and including sustainability aspects.

Copies of the papers are provided in Part 2 of this document. Profiles of each of the authors are provided in Appendix 2.

Following the presentation of all nine papers, a plenary discussion was held with the aim of establishing four or five key topics which needed further consideration, and that could be addressed in working groups in the afternoon session.

Following lunch, the workshop divided into four separate working groups and following about an hour of discussion, each of the groups reported back on conclusions of their group, including potential R&D priorities.

The day concluded with a plenary session that had the aim of determining some further directions for the development of a wattle seed industry, and identifying the most important R&D priorities.

2. Summary of Presented Papers and Related Discussion

2.1 Summary of Presented Papers

Economic Potential for a Wattle Seed Industry (by Sarah Simpson and Peter Chudleigh)

This paper draws heavily on the report titled “Wattle Seed Production in Low Rainfall Areas” (Simpson, S. and Chudleigh, P., June 2001). This report was the result of a desktop study commissioned by RIRDC in late 2000.

The aims of this study were to investigate the potential for broadacre wattle seed production in the medium to low rainfall areas of southern Australia while considering the implications for resource sustainability, and the potential for wattle seed to penetrate large-scale markets.

The following conclusions were drawn:

- It may be possible to develop niche or intermediate markets for wattle seed (eg increased bushfood demand, low glycaemic, specialty flours, oils). High volume markets such as starches, vegetable proteins etc would also be possible but would depend on seed being able to be produced at very low cost, for example significantly less than \$1 per kg. It may also depend on some unique properties being discovered to ensure wattle seed is competitive.
- Interactions with harvesting, species selection and co-products are very important when considering characteristics of production systems such as layout.
- Wattle seed production could contribute to increased water use over annual crops and pastures. However the extent of such contribution to lowering groundwater tables and reducing the impact of salinity has not been quantified.
- Harvesting is a key cost component and a significant driver of the economics of wattle seed production. There are several harvesting options that can be explored.
- The three key drivers of the economic viability of wattle seed production are the harvesting method and subsequent cost, the yield and the farm-gate price. Some scenarios show promise of being economically viable, however it is stressed that the assumptions used in the economic analysis are indicative only, and further work is required in order to confirm or identify more accurate parameters.

Building a Large-Scale Wattle Seed Industry (by Graeme Olsen)

A large-scale wattle seed industry, based on suitable species in the *Acacia* genus, could provide substantial land management benefits in dryland agricultural areas in southern Australia. This paper discusses market opportunities for wattle seed, and some production issues that determine its potential profitability.

Wattle seed could be sold in a number of different sized markets, ranging from niche markets for bushfood and other specialty uses, to small to medium-sized markets for nuts, snack foods and pulses, and large markets for staple grains, oilseeds, food ingredients and stockfeed. At each step up in market size there is a corresponding step down in market price.

The development of row-crop harvesters should bring significant reductions to harvesting costs for the wattle seed species in current use. This harvester development path could suit a small to medium-sized industry based on high value seed, but it will reach its limits long before becoming competitive with broad acre grain production systems harvested by headers.

A more promising development pathway for large-scale crops is to develop a wattle crop with a different morphology – one that has many features in common with broad acre crops, enabling it to

be grown in paddock layouts, and to be harvested by equipment with similar efficiency to conventional grain harvesters. Desirable features in the plant include short stature, reasonably erect form, high ratio of seed production to vegetative growth, formation of pods and seeds at or near the top of the plant, large seed size, synchronous seed ripening, and reduced or inhibited pod shattering.

When developing a new crop, it is important that key aspects of farming system design are considered simultaneously. Important issues for wattle seed development are species selection, crop design, management methods and harvester development.

At a broader level, requirements for new crop development include:

- suitable germplasm
- efficient, integrated farming systems
- appropriate growing, harvesting and processing technology
- acceptable product quality
- market penetration

Does wattle seed have the potential to become a major food crop? It's too early to say, but further investigation is warranted. *Acacia* is an extremely diverse genus, with about 1,000 different taxa identified in Australia. A proper investigation of this variability may find suitable species or populations from which successful new crops can be developed.

In conclusion, it seems likely that further development of existing tall wattle seed species and associated harvesting technology will enable the industry to grow from a niche industry to a small industry, but this pathway will not lead to the development of a large industry. To achieve that goal, and its associated land management benefits, a different development path is needed – one that selects and develops new germplasm better suited to efficient management and handling.

The Opportunities for a Cultivated *Acacia* Industry (by Charles Littrell)

Australia's rural economic, ecological and social strategies helped convert a distant penal colony into one of the world's richest countries. These strategies are proving unsustainable over the long term, however, and to remain a rich country Australia needs to develop new rural land uses.

This note discusses one candidate strategy: growing *Acacias* for human food, through wattle seed production.

Australian Native Produce Industries (ANPI), the leading firm in commercialising native food plants, has committed human and financial capital to developing the wattle seed industry. ANPI intends to build a public/private consortium to conduct initial R&D.

To develop its first generation production system, ANPI must secure answers to the following questions:

- a) Food Science. What are the seed's macro and micro nutrient properties, anti-nutritive properties, and potentials for use on a stand alone and ingredient basis? What special properties, if any, do wattle seed kernel, hull, and oil possess? The answers to these questions determine the likely maximum and minimum wattle seed price in commodity production volumes.
- b) Production and Yield. Which species make the best foundation for a commercial *Acacia* industry? How should we efficiently establish these species, and in particular what microbial and other sub-soil preparation is necessary for establishment? What production systems (grid pattern, co-production plants, cultivation techniques) are likely to work best? What yields might we expect in commercial cultivation?
- c) Harvesting Cost. What harvesting and post-harvesting systems are likely to produce the best production cost outcome?
- d) Environmental effects. How can we ensure that *Acacia*'s environmental benefits as a wild plant are maintained in commercial cultivation? How do we value these benefits in economic terms?

- e) Forest products strategy. How can we manage and maximise the economic outcomes from *Acacia* coppicing by-product?
- f) Plant Selection and Improvement Strategy. How do we select our initial cultivars for first generation production? How do we then move to improved commercial hybrids?

ANPI is confident that food-oriented *Acacia* cultivation is a legitimate candidate, hopefully among many candidates, to replace some existing rural land use with more profitable and sustainable new uses. We are now moving from pre-feasibility to first phase R&D on this candidate.

Genetic Factors Influencing a Wattle Seed Industry and Scope for Genetic Improvement (by Tim Vercoe)

Acacia is an extremely diverse plant group in the Australian landscape with 1165 taxa (Flora of Australia Volume 11A and B). There are forest trees reaching over 30 m in height, shrubs and ground covers, and the genus is represented in most major Australian ecological regions. Fewer than 100 taxa have been documented as producing edible seeds eaten by Aboriginal people, but the genus is a major food source for native fauna.

Based on previous work with these and other species, the seed improvement process would proceed along the lines of -

1. Systematic sampling from a set of natural provenances to capture the genetic diversity present across the geographic ranges of target species/species complexes.
2. Evaluate species and provenance performance in well-designed field trials to yield information on environmental tolerances, seed yields and seed nutritional factors.
3. Identify best natural provenances and establish further experimental plantings.
4. Make selections (either by collecting seed, or by vegetative propagation) from initial trials and later plantings of best provenances, based on an understanding of population diversity and some readily measured productivity and nutritional parameters.
5. Use the selections to establish breeding populations (for outcrossing species) or, in the case of self-fertilizing or apomictic species, for multiplication gardens where seed of desirable genotypes is multiplied. These stands would form the breeding population for intensive selection and breeding.
6. In some cases it may be possible to develop the first experimental plantings (activities 2 and 3 above) into interim seed production areas.

Opportunities and Constraints for Developing Large Scale Markets for Wattle Seed and its Components with a Specific Focus on Health and Nutrition (by David Topping)

Most of the current drive to grow and use wattles seems to be agronomic, for example drought resistance, soil improvement capacity etc. The sole existing nutritional attribute of *Acacia* plants in a western industrial context is the exudative gum (Gum Arabic) from *Acacia senegal*. Scarcity of this gum could assist in developing an Australian industry around wattles however it is unlikely to be enough by itself to sustain a broadscale industry.

The potential useful fractions of the *Acacia* plant for food and medicinal use include:

- Gums and mucilages (seeds, exudates) – food ingredients
- Leaves – forage, tannins
- Seeds – protein, gums for food use

Some of the overarching issues are:

- The cost to benefit ratio for producing a food ingredient like soluble non-starch polysaccharides (NSP) is high, that is a high cost for limited benefit. However if a potential anti-cancer agent were discovered, the costs would be low relative to the eventual benefit.

- Speed to market is a major issue and depends on the need for toxicology or substantiation. Food processors are unlikely to be interested in assisting the development of a food ingredient that will be costly and will take a long time to reach the market.
- If it is considered a novel food or ingredient, then there may be constraints in terms of proving safety or efficacy.
- Supply may be a constraint. For example, will it be possible to produce enough wattle seed or gum to guarantee a reliable supply to the appropriate markets.

Opportunities and Constraints for Developing Large Scale Markets for Wattle Seed and its Components with a Specific Focus on Food Processing (by Ragini Wheatcroft and Rachel Kelly)

The protein, fat and carbohydrate components of wattle seed are comparable to pulses, particularly chickpeas. The wattle industry will most likely compete with other pulses. The current status of the wattle industry is:

- 6 tonnes of wattle seed is utilised, though there is an existing demand for 12 tonnes. The nearest pulse category in terms of volume is mung beans (17,000t ethnic food, bean sprouts)
- comparable nutritionally to pulses
- anti-nutritional factors have been reported
- nothing is known as regards allergenicity or digestibility
- the level of processing is low
- markets are likely to be based on speciality and novelty, eg green clean image to place it in a different category to chickpeas as a high value, trendy bush food for restaurants, rather than an Asian commodity export.
- cost of wattle seed is \$35,000/tonne compared to \$250/tonne for chickpeas

The limitations to a large scale market include:

- A technological breakthrough is required to support development of new markets for wattle seed ingredients.
- Does wattle seed have a competitive advantage, for example there will be competition from pulses?
- Can wattle seed produce ingredients that meet sufficient functionality needs for many applications?
- Can wattle seed be produced at a cost that allows it to be sold at a price the consumer is willing to pay?
- Will geography be an issue? For example, considerations are shipping costs, handling and storage stability, shelf life.

Opportunities and Constraints for Developing Wattle Seed and its Joint Products as Animal Feeds (by Tony Schlink and R.A. Dynes)

Trees and shrubs have long been considered important for the nutrition of grazing animals in Australia, particularly where the quantity and quality of pastures is poor for pronounced periods. Foliage, seeds and pods from trees and shrubs have the potential to provide both protein and energy supplements during the annual feed gap in Mediterranean environments or during droughts. Several *Acacia* species are recognised by graziers for their drought feeding value. The economic value of these species to animal production will depend on when the nutrients are available (i.e. does foliage/seed/pod production match feed gap or drought) and the concentrations of essential nutrients and secondary compounds.

Animal utilisation of *Acacias* in farming systems could be improved through selection of *Acacia* species, which will establish and provide feed for livestock during feed gaps and droughts, providing issues of fodder accessibility and secondary compounds are overcome. Successful selection will require simultaneous determination of yield, nutritional and anti-nutritional factors for ruminants followed by animal studies. To-date the potential of *Acacia* species for animal production has not

been studied in any systematic fashion to determine the potential of any of these species for animal production in Australia. This situation exists despite the extensive use of the species in periods of nutritional stress and increased plantings of *Acacia* species of unknown nutritional value for potential livestock production.

Water Use and Sustainability of *Acacia* Crops in Southern Australian Agricultural Systems (by John Bartle)

Acacia is a large and diverse genus with a wide range of plant form and function. It provides a large base from which to select germplasm with potential for commercial development. Selection of germplasm can be approached from two directions:

- selection based on biological characteristics that are desirable for a crop plant.
- selection based on the potential for production of commercially attractive materials.

These two categories of selection criteria are interrelated, i.e. the biological potential may help determine what the best product might be, or alternatively, the desired product will influence the selection of biological attributes.

By far the dominant objective in the development of new crops is scale. If we are to entertain remedy of the serious problems of salinity and sustainability in southern Australian agricultural systems, then we must be thinking of new 'sustainable' crops that could be planted on a very large scale. These crops will need to have a presence, at least intermittently, on virtually every hectare of agricultural land. Hence this overview will focus on *Acacia* as a source of germplasm that might have very large-scale application. It will approach this from the direction of the biological attributes of *Acacia* that will be desirable for large-scale crop plants.

The genus *Acacia* will not be the only candidate to be scrutinised for sustainable crop development prospects. The task of developing perennial crops to help make Australian agriculture sustainable will take a couple of generations and many millions of dollars of R&D investment. However, this investment should, at every stage and for every option, be based on rigorous assessment of likely comparative return on investment in the long term.

Hence the question addressed in this overview is – what biological attributes of *Acacia* make it attractive for crop development and what are the most prospective directions for investment in *Acacia* R&D?

Options for Harvesting Wattle Seed (by Bill Kerruish)

Simpson and Chudleigh (2001) refer to four general concepts. These included: the traditional manual method used for harvesting seed for speciality foods, individual tree shakers as currently used for olives and some nut crops, and continuously moving strippers and biomass harvesters that would move along a row or rows of plants.

In this presentation the traditional or mechanised methods of harvesting individual trees are not included as they are inappropriate to the large scale, low cost harvesting of such a crop. A continuous moving machine is considered necessary for the efficient harvesting of small trees (Kerruish 1976) and the likely costs of harvesting wattle suggested by Simpson and Chudleigh tends to confirm this decision.

The options considered fall into two categories, those that harvest seed only and those that harvest some or all of the above ground biomass to recover the seed, with the remaining components being harvested for some other product or returned to the site.

Important gains may be made in plant breeding and cropping trials but the best outcome will be achieved by pursuing this goal in partnership with the ongoing analysis of operational alternatives. Further work should involve:

- The selection of species most suitable for seed production and the establishment of trials to establish likely cropping patterns.
- The continuing analysis of different technical solutions and management strategies, drawing on the best available biological, operational and economic information.

Examples of such analysis are provided to suggest how this might be done.

The developing and testing of critical components, such as mechanisms for dislodging and recovering seed from growing plants, should proceed after further work on crop development and the identification of the more promising cropping patterns have been explored.

2.2 Questions and Discussion Following Presented Papers

Following every second or third presentation, workshop participants were given the opportunity to ask questions of the speakers, or make comments on the presentations. Some of the key themes, clarifications and additional material to come out of those discussions are presented below.

Production on Least Productive Land

There was debate as to whether a wattle (or any other agroforestry species) production system can in fact be productive if it is established on the least productive land in a paddock or property, as has been proposed as an initial establishment option. The point was made that *Acacia* plantings for wattle seed production are initially likely to occur not on the least productive land, but on the land least profitable for grain production. This relates not only to the soil productivity and structure, but also the landscape and geography. In addition, *Acacia* requires less inputs than wheat and is more robust to mistreatment. In many cases it is a pioneer species. However, it was further pointed out that there is a difference between survival and productivity.

An additional aspect introduced was that one should be looking at the profitability of the whole farming system. For example there are desirable reasons for alley farming and this may present a niche to grow wattles on productive and profitable land by integrating farming practices. The grazing of cattle or sheep between rows can change the entire economics of production.

Other solutions to ensure maximum economic benefits without a large opportunity cost in terms of taking good land out of grain production include:

- if wattles are planted in areas that recharge water tables under good wheat land, then they can reduce the watertable under the productive wheat land, improving the sustainability and future productivity of the farm as a whole.
- the consideration of different soil types – some soils are not productive in terms of grain production, but can still be considered productive for other species, including native forest species. For example, some of the Western Australian sandy soils have poor wheat crop returns, but hold wood crops quite well.

Brief mention was made that *Acacia* for wattle seed production is only one alternative for establishment on these 'less productive' lands and that wattle may compete with other forest crops eg wood fibre. However other participants did not consider wattle a competitor to oil mallee and other forest crops. They pointed out that diversity will be important and there will not be 'one big idea' for land use. In response to this, the original point was clarified that wattle seed will be competitive with oil mallee etc in terms of scarce R&D money and therefore money will have to be channelled into the 'best bang for the buck'.

Tree Density

There was some concern that the stems per hectare in the economic analysis of the Simpson and Chudleigh report is too high, and the 625 stems per hectare assumed would more likely relate to an

irrigated option. An alternative assumption of density was 400 stems per hectare. There was also concern that the assumed yield would be difficult to obtain in a dryland situation. It was acknowledged that this may be the case, and that the yield assumption was based on an improved, not wild, stand of trees. That is, the yield assumptions pertained to a future production system following a significant amount of research and development.

Size of Competing Markets

In several of the presentations, statistics were presented to demonstrate the current size of the markets for various commodities to show the potential size of the industry in which wattle seed may compete. Examples of commodities considered most appropriate to target included beans, chickpeas and other legumes. There were some significant differences, however, in the size of the markets presented from different sources (United States Department of Agriculture (USDA) and Food and Agriculture Organisation (FAO)) and this was the subject of some discussion. It was postulated that the FAO statistics most likely related to commodities traded internationally, while the USDA statistics most likely related to commodities traded both domestically and internationally. The difference in these statistics is important as what is sold within a nation is generally not sold at the same price as exports, therefore it is important to compare the size of markets that can be targeted for a certain price.

Following this discussion, it was suggested that the critical first phase research should be food and nutrition and initial processing. The kernel, oil and husk are separate products and it needs to be determined what can they be used for and at what price. This would then determine the production system to be developed, that is, whether competition is with pulses or whether animal feed markets are being targeted.

Pests and Diseases

It was pointed out that many of the presentations seemed to wrongly assume that as *Acacia* is a native species, and already adapted to Australian conditions, there would be few pest or disease problems associated with the production system. It is in fact the case that any species planted in a broadacre, monoculture situation will develop pest and disease problems. Workshop participants acknowledged this and indicated pest and disease management would be a consideration in the development of the production system.

Establishment Costs

Various presentations included estimates of \$300 to \$380 for establishment costs. Some workshop participants knew of farmers who were establishing *Acacias* for a fraction of that cost with direct drilling. While a more precise breakdown of this figure could not be provided, it was stated that it was based on a contractor rate of what an investor would pay, rather than what growers could establish *Acacia* for with their own equipment. The \$300 figure was also more applicable to direct drilling of eucalypt seed that is very small and is more trouble to protect from weeds and insects. *Acacia* in general may have a lower establishment cost than that quoted as it has a significant advantage as a source of domestication due to its large seed size factor.

Harvester Development

There was a debate over approaches to harvester development. One approach is to adapt harvesters that already exist on the farm for the purposes of grain harvesting. However to do this the *Acacia* would need to meet certain limiting factors, for example height, seed pods on extremities, and uniform ripening. Some believe that this use of existing equipment may be the lowest cost option in the case of broadscale establishment focused on wattle seed production with less regard to co-products. An example of where this approach has worked was with the development of mung beans

and chickpeas, where the original breeding objective was to change the plant's habit so they could be harvested with the equipment already on the property.

Others in the workshop disagreed fundamentally that to start with existing harvesting equipment would be the lowest cost option. There are many options that are likely to be presented and developed, and to start off with that assumption as an exclusive consideration could be dangerous. While it is an important option and should not be excluded, one should not focus on a piece of machinery because it is widely available. That is, the available machinery should not be the driving factor in the development.

It was further acknowledged that other woody plant crops to be developed will require completely new harvesters – so both options are still available. Wattle seed can fit into the existing harvester mould or a new woody plant harvester mould.

Diversity of Species

Wattles flower in every season and month of the year but it seemed implicit in many of the presentations that particular species would be grown on particular properties. The question was asked if it is possible for one property to have a diversity of species so a contract harvester can be used all year round in a region.

It was acknowledged that this is a definite possibility, and that a diversity of species may in fact be very important for several reasons.

- Firstly, it is correct that different species flower at different times. Quite a lot of seed could escape if one had a 100 acre crop of one species which resulted in a short harvest window. The point was made that if you have a diversity of species across your landscape the key is finding the formula that will fit the climate and land suitability in a particular area and this will vary from region to region.
- Secondly, it was pointed out that diversity of species may result in environmental benefits, including water use, where different species may have different rooting depths and different water extraction characteristics at different times of the year.

It was suggested that the first one or two generations of development of woody crops should be setting out to biologically diversify the agricultural base, so a range of niches can be filled and a complex and robust system can develop.

3. Development of Discussion Topics

3.1 Introduction

Peter Chudleigh opened the third session of the day by re-focusing the participants on the workshop objectives. The first objective had already been achieved, that is, to get as much information as possible on the table. The objective of the remainder of the day was to assist RIRDC, with their scarce R&D money, as to where to focus those resources.

When assessing a broadscale wattle seed industry it is important to remember the ‘broadscale’ component as JVAP is not focused on niche products, rather it is interested in the opportunities for commercial solutions for rising watertables and salinity. It is important to place a broadscale wattle seed industry in the context of other species that might be grown to achieve the desired sustainability benefits. Also important will be determining if there are R&D priorities common to developing a small-scale industry and a large-scale industry.

The final objective is to determine future activities including R&D directions. What do we do next? There is a whole range of interacting factors and it will be difficult to prioritise what to do first, and exactly what to do.

Based on the presentations and the discussion following the presentations, the following possible discussion topics were suggested by Peter Chudleigh in order to encourage discussion:

- What are the prospects for developing a wattle seed industry? In developing new industries one usually starts with the market but the presentations this morning seemed to indicate that we don’t know a lot, but from what we do know there doesn’t seem any great potential unless some unique, and desirable feature is discovered through further research. Will the market be a killer factor?
- Production systems (including the plant itself) and how it can be adapted to be not only commercial in a production cost sense, but also produce a product desirable to the market. A systems approach will be necessary to achieve this integration.
- There are scarce R&D resources so how do we put these into the best areas – do we prove the market first; do we look at the plant first and what it has to offer; do we look at the breeding first; or do we look at harvesting first?
- One of the major challenges will be defining the key factors that will allow us to have enough knowledge to say that this industry might or might not have good prospects.
- Other opportunities for addressing salinity – the context for ‘perennializing’ agriculture and where does wattle seed fit into that?

3.2 Discussion

A Grower’s Experience

Barry Clugston, a wattle seed grower from Wimmera in Victoria, was asked to open the discussion by providing some general details about his operation, and from his experience, what he sees as some relatively urgent R&D priorities.

- Agronomy is a major problem – it took him 6 years to learn how to grow a wattle tree.
- Harvesting is one of the most critical things. He currently does it by hand and a lot cheaper than figures he has seen quoted in the presented papers. He sweeps the seed and pods off the tree with a pipe as in an olive situation, sometimes using a labour team (eg backpackers). The seed and pods are then collected off tarpaulins.
- With handbeating he can revisit the tree up to half a dozen times and keep knocking off seeds as they ripen as they don’t all ripen together. He has learnt that you can start harvesting a lot earlier

than you think so you don't lose seeds to the wind by waiting. You can get nearly 100% recovery.

- He does not believe buttshaking is a harvesting option – it can damage the tree, the pods won't easily dislodge; and all aren't ready to come off at the same time.
- Finger processing seems the best line of research as it will physically knock the husks and seed down together without much loss of leaves.
- He would like to be able to produce a truckload off his property and take it to a processor. With that type of bulk the processor will have incentive to try looking for markets and uses.
- At the moment he generally produces a ute load full for the restaurant trade and there is no incentive to search for larger markets
- Economics is an overriding factor, but in some situations the economics will go out the door in comparison to the loss of land to salinity. If we don't address water balance and get out of shallow rooted crops and into deeper rooted perennials the landscape will be in trouble – in the end the plantings won't be economically driven, they will be landscape driven.
- While he has never physically inspected the depth of the roots of his plantings, he is confident the trees are drying up some of his paddocks because he is not filling dams at the bottom of the paddocks. Taller grasses also may be contributing to water reduction.
- He is not concerned with weediness as he slashes between rows.

Background to Discussion Topics

For the discussion topics, it was determined that a group on the market prospects was essential, as some consider this the most limiting factor. What size market will be the most profitable or realistic to target? What sort of human products could start to meet that broadscale environmental market? This would also help to decide the proportional effort of R&D resources that should be put in to developing a specific wattle seed industry or a wider *Acacia* industry. There is a need to do some basic work to consider, for example, exactly how large the bean market is. If we're going to aim for a bean market, what are the special things about wattle seed that allow it to compete with chickpeas or mung beans?

The markets for co-products (eg biomass and residue for livestock) also need to be considered. Co-products might be driven by the type of production system that is designed, or co-products themselves may drive the production system with wattle seed as a co-product. It was suggested that in a lot of cases co-products may not be entirely compatible, and may require divergent streams of development.

It was also recognised that there is a lack of knowledge on the types of products that can even be produced from the seed. It is possible due to the number of species that there are opportunities not even considered yet. For example, there is awareness that the seeds of some species are extremely oily, however it is not known whether those same oily seeds also have toxic or perhaps anti-cancer qualities. This level of basic research is still required. However it was pointed out that the actual number of species you could get seed from are far less than 1,000 – and then what can be grown in a particular micro-climate and district are less again. It will not necessarily be a complex process to do the initial screening for species that should be considered.

It was determined that it would be impossible to separate the issues of plant/seed characterisation and functional food characteristics from the market opportunity side. That is, both issues of what is physically, or technically possible to produce, versus what the market requires or is willing to accept, need to be considered.

It was suggested that the market prospects aspect is probably the key to this whole industry development but in order to assess the market properly, comprehensive information on not only the chemical constituents and food properties, but also what can be done with those in a manufacturing sense is required. All of these aspects have to be looked at together in a cycle. Once a little bit more is known about the market prospects the seed characteristics can be interpreted and so on.

A suggestion was made that from the food processing point of view, any advantage to wattle seed will only come if it offers some specific property that can't be met at the moment with other products. To link it back to markets, there is some value to understanding how the isolates actually function in food systems, for example what are the emulsification and foaming characteristics? It is very difficult to get ingredient suppliers taking up something new and developing it unless it is a new property that can't be met with other existing products. It is necessary to go back to what the needs are at the community level in terms of public health and nutrition. With the current knowledge, what is in wattle seeds does not seem to give an extra dimension in terms of fulfilling any needs. So far what exists is an ingredient or food that has quite a lot of cachet with being Australian and the agronomic use is probably going to sell it – there may be things that come out that have nutrition and health benefits.

It was noted that since wattle seed was unlikely to drive industry development on its own, it may be first useful to establish if wattle is indeed a useful tree for addressing waterlogging and salinity.

Other participants were more focused on identifying an economic driving force for the creation of a new broadscale industry that would address the natural resource management issues. The first issue is one of assessment of whether broadscale wattle seed production can be commercially driven. If the answer is no, then we should move to some other commercial prospect and relegate wattle seed to a small scale market.

3.3 Discussion Groups

The four discussion topics were as follows:

1. Wattle Seed in the Context of Other Woody Perennial Crops
 - Is broadscale production feasible/desirable/economically competitive
 - Is information sufficient to make such a comparison? What information is needed?
2. Market Prospects
 - Food processing and nutrition
 - Unique characteristics
 - Size of target market
 - R&D priorities
3. Production Systems
 - 1,000,000 tonne market – Design a production/harvesting system for as 1 million tonne market
 - Develop R&D priorities
4. Production Systems
 - Design a production/harvesting system for a 100,000 tonne market
 - Develop R&D priorities

4. Outputs of Working Group Discussions

Each of the four topics was discussed by a working group for about one hour, and a representative of each group then reported back to the workshop on the findings of their discussion in relation to their topic.

4.1 Wattle Seed in the Context of Other Perennial Crops

The group started with the proposition that there are many different products that could be produced from perennial crops, and that they need to be looked at systematically to see which of these products might have a place in broadscale agriculture. This was essential in order to determine how attractive wattle seed as an industry might be compared to other options.

Perennial agriculture as a whole will always have to compete with annual agriculture. Annual agriculture currently exists in many of the target landscapes and perennial agriculture including wattle seed will have to be as profitable as or more profitable than annual agriculture (including consideration of sustainability issues).

Product competitors include:

- Annual grains
- Meat/wool (co-production)
- Composite wood
- Process wood/charcoal
- Bioenergy

Likewise, on the plant side, there needs to be an understanding of the attributes of other plant groups and species that wattle seed will need to compete with. A process of systematic evaluation should be established to determine what the priorities should be.

Wattle seed competitors include:

- Other *Acacia* products
- Other plants
 - Eucalypts
 - Perennial pasture/fodder
 - Other plant groups

The elements of interest or attraction in looking more closely at wattle seed were identified by the group:

- It is the only perennial plant with a reasonable claim to being a human food producing plant in terms of dryland agriculture in the extensive wheatbelt zone.
- The wattle seed possibility enhances the attractiveness and economics of the *Acacia* genus.
- The production of wattle seed could be widely applicable to a range of landscapes and climates.

The R&D priorities identified by the group include:

1. Food science efforts to characterise components and food processing attributes
2. Co-production possibilities
 - Forest products such as wood and biomass
 - Animal use such as grazing between trees as well as tree products used as feed

4.2 Market Prospects

The group started with two assumptions

- Wattle seed is seen as a candidate for an economic driving force for broadscale revegetation, ie, not wattle seed for the sake of it, but as an economic solution.
- While wattle seed or other wattle food products such as gum can be explored, it is acknowledged that a range of other 'competitors' are currently being investigated.

At this stage it appears there is very little that is attractive about wattle seed as a major food crop. There are currently no known constituents that can be commercialised in a broadscale sense, however there are markets for niche products.

Product opportunities to be further explored include:

- gum (not from seed but from the trunk)
- novelty oils (from arils attached to the seeds)
- other aspects of the seed may be of interest and should be investigated to determine, for example, if there are any sterols that can be used for cholesterol reduction.

Bio-prospecting is a method of searching for novel properties of a new crop such as wattle seed. Bio-prospecting for medicinals is extremely high risk and very costly and not appropriate to consider in the early stages of product development. However bio-prospecting for food properties is relatively low cost and simpler.

At this stage it is difficult to quantify the potential size of markets until the properties of the product and how they might address market requirements are known.

The group identified the following R&D priorities:

- A review of prospective food constituents or properties that are in demand; for example identify food properties that have scope for development
- Target the key species of wattle for investigation of their food properties that may fit into some of these potential areas of development
- A review of legislative and regulatory hurdles for new products.

Following the presentation there was a brief discussion as to the possible contribution of traditional aboriginal knowledge about *Acacia* species and wattle seed to help speed up the 'western science' bio-prospecting process. It was determined that this knowledge would be useful in terms of bio-prospecting for food properties and helping to shortlist species that have known food uses. However it would not be so relevant in terms of bio-prospecting for medicinal purposes as aboriginal people did not traditionally suffer from high cholesterol, cancer or diabetes, which would be some of the major medical issues potentially being considered.

4.3 Production Systems (1 million tonne market)

The group considered the following to be the major characteristics/assumptions of a production system capable of delivering wattle seed to a 1 million tonne market:

- Low yield crop in terms of seed production per stem
- Dryland agriculture
- Harvester will have to move quickly and process as many hectares per hour as possible (possibly at speeds of up to 10 km per hour) in order to compensate for the low yielding nature of the crop
- Direct seeded crop
- Harvest height to be a maximum of 1 to 1.5 metres so the machine will pass over the top of the crop

- Maximum seed per hectare may be influenced significantly by plant density and layout (anywhere from 5,000 stems per hectare down to 400 stems per hectare). This will be a fairly fertile area for R&D as the full range of possibilities needs to be considered to maximise yield per ha.
- Layout issue in terms of land conservation is that there is a choice between continuous plantings (eg plantations) right down to belts of various widths. There are land reclamation and dewatering/salinity implications depending on whether one uses phase cropping with the intention of mining the water or a longer life repeated harvest method.
- The harvest platform would be mobile, highly manoeuvrable and have a 5 to 10 m wide front. If it is any narrower it won't get the throughflow per hour needed to minimise the cost of harvesting seed.
- An area for R&D is the interaction between spacing, yield and harvest method and that would also tend to relate to whether the layout is for a continuous phase crop etc
- An ideal goal would be early occupation of the site, maximum leaf area and maximum production per ha as early as possible. However the further the system is pushed that way, the greater the risk of drought death before the crop has run its term. If it is a phase crop and its going to be entirely harvested for biomass at say five years of age, then the system can be pushed further in terms of heavier seed, higher occupancy and earlier production.
- A picking system (eg fingers versus knives) can not be nominated at this stage until there is a more complete understanding of the plant.
- The seed should be separated on the harvester as early as possible in order to avoid foliage and other material contaminating the seed
- It is a grain not biomass harvesting operation. Biomass harvesting is a different principle and the development of the biomass harvesters and grain harvesters diverge very quickly.

Comment was made that separating the seed on the harvester itself is usually not possible as the wattle seed will be at varying stages of maturity, and the green seed does not separate from the husk until it has been dried in the hot sun for a couple of weeks.

It was pointed out, however, that for an industry on the scale proposed, uniform ripening would be necessary as the cost of rehandling would be difficult to accommodate when competing with a commodity like wheat. It was also recognised that uniform ripening will be an advantage in terms of food processing, as any differential in the seed due to whether it matures on the tree or not will be a problem for food processing.

There was also some discussion as to whether a biomass harvester may in fact be appropriate in this situation so that a single harvester could be used to harvest two products at once. However, it was pointed out that biomass requires a row crop harvester which takes huge volumes of material, weighs 15 to 20 tonnes and has 400 kilowatts of power on board – it is a cane harvester style of machine which is very heavy, expensive and powerful and processes between 70 and 100 tones of material per hour. A grain harvester is a sheet metal box which is cheap and light; it harvests only a small amount of material per hour and it needs a very wide front because grain provides only a low yield per hectare.

It would be possible to opportunistically take seed from a biomass harvester. However, seed would not be the focus of the biomass industry and may therefore not fit into the 1 million tonne market category. It was recognised that this might provide an economic opportunity but is more appropriately discussed by group 4.

An argument was made that any wattle seed industry of this size is a long way off, as the industry will develop through the higher value markets and as the tonnages increase over time there will be a critical mass on which to base further research. It will not be possible to launch straight into broadacre production for large markets. It will be necessary to go into high value markets incrementally.

Following this group's presentation, the conclusion seemed to be that research in the 'production systems' area should not be the first step, but rather the market should be studied first, and the

genetic resource should be investigated to determine if it is possible to breed a wattle plant that will fit into this type of broadscale production system.

4.4 Production Systems (100,000 tonne market)

Points raised by this group include:

- One of the key characteristics of a production system on this scale is diversity.
- This size production system is likely to be associated with co-products.
- There are a range of possible production systems including alley farming, whether 15 or 100 metres wide.
- Another production system could be extensive grazing with low food quality *Acacias* which may have a high digestibility for animals. This might be useful where you can't get perennial pastures to persist in cleared land.
- If considering production in cropping areas the less profitable parts of the paddock or farm could be selected for production
- Opportunity seed harvesting could be a tool for these production systems. Eg Grazing may occur most of the year but at certain times seed may be harvested as a food product.
- There will be a balancing act of human and animal consumption of the plant or seed. This may depend on cost-benefit analysis of the different genetic resources in *Acacia* and how they may be exploited.
- Quality, volume and processing needed are also major points. For example, it may not be worthwhile harvesting *Acacia* seed for animals if the yield and processing makes it too expensive.
- Other production possibilities for *Acacia* include bio-energy, woodchips, pulp, and effluent recycle use for feedlots.

R&D needs identified by Group 4 included:

- Evaluate and select species and bio-types with various characteristics in order to have a range of *Acacias* for different purposes; for example there is currently different varieties of wheat for feedgrain, for high quality pasta and breadmaking. Various uses can be regional and can be human or animal specific. This opens a range of funding opportunities by approaching other R&D Corporations.
- In terms of management R&D is required on all aspects of agronomy and silviculture including plant density, water use efficiency, fertiliser use etc.
- A mechanical harvester needs to be developed.
- Ultimately it would be desirable to have a series of establishment packages specific to the end product use (eg human or animal consumption).

5. Plenary Discussion

The following key points were established during the Final Plenary Discussion:

- It was determined that there are prospects for wattle seed, however there is not enough knowledge to compare wattle seed with other commercial perennial opportunities at this stage.
- The size and shape of any future wattle seed industry is uncertain and will be dependent on many factors.
- In terms of research into wattle seed, some of the basics are still unknown, for example is the oil valuable, is the husk a waste or by product, what sort of ingredient is the kernel etc. Knowing these basic details will give a basic sense of what wattle seed will be worth at different levels of production.
- The legislative and regulatory issues need to be looked at up front. This is relatively low cost and easy to do.
- It can not yet be determined whether wattle seed is a research area more appropriate to JVAP or RIRDCs Bush Foods Program.
- Any R&D should be in proportion to R&D on other crops that might also be targets for development. There is a limited amount of money for R&D in this area and the major opportunities need to be picked out. It is very clear that *Acacias* are a very interesting plant group and there is almost certainly germplasm in the genus that will be developed into a whole series of crop plants over the next few decades. The seed component is one *Acacia* product that should be monitored and it should be worked on in proportion to its perceived priority over time.
- The amount of funding available might dictate the priorities. That is, one should consider the highest affordable priority.
- A continuation of desk top research is an affordable way of moving the research forward.
- For some potential products, there is a critical mass point of production of wattle seed that will need to be reached before any R&D can be carried out. For example there may be opportunities in animal nutrition in terms of feeding the tannin containing wattle seed husks to dairy cows as an anti-bloat measure. However, to undertake a small trial would require 2 to 2.5 tonnes of husk. Similarly, to do human food experiments on pigs will require 60kg of food grade product per treatment.
- It was indicated that the first steps in terms of analysing the wattle seed for potential food opportunities would be fairly simple and relatively inexpensive (eg analysis of composition of non-starch polysaccharides (NSPs), starch). However one must consider that at the earliest stages it will be necessary to cover a wide range of the germplasm pool. Also, there is great variability within the seeds of a single *Acacia* species as there has not yet been any chance to 'breed' this variability out.
- In order to sell wattle seed as an ingredient to a processor, you will need to know and guarantee the exact composition for inclusion on a nutritional information panel. A standard product needs to be delivered to the food processor as they are relying on it to perform in exactly the same way every time. Therefore the variability will need to be bred out of the wattle seed before it can be processed as an ingredient. However, it needs to be determined what characteristics are desirable in the market place before any moves can be made towards breeding variability out in a certain direction.

The following broad list of knowledge gaps and R&D priorities were identified:

- Support existing Search, Florasearch and Acaciasearch projects. The methods developed in these projects will aid a comparison of wattle seed with other woody perennials
- The food science area is very important. We need to know more about what is in both the seed and the plant (eg gum from trunk).
- There should perhaps be an *Acacia* program rather than a wattle seed program as there are many potential products from the *Acacia* genus.
- Bio-prospecting in regards to food ingredients should be effected from both the supply and demand side, but particularly on the demand side. A first step might be a review of the food ingredients that are in demand at the moment and are likely to be in demand in the future.

- On the supply side we know insufficient about the species and what they contain to meet those food ingredients being demanded.
- A legislative and regulatory review is one of the first activities that should be undertaken.
- There is a need to take a systems approach in any investigations. A systems analysis in the form of a desk top study should be undertaken before funding field trials.
- This desktop study may include a comparative systems approach (economics with an emphasis on primarily biomass production versus primarily seed production). This will include aspects such as:
 - Layout – maximise seed yield
 - Spacing/yield/harvest interactions
 - Screening species for market, nutrition, shape of tree etc
 - Species selection
 - Management – agronomy/silviculture/harvesting
 - Water use

The plenary discussion raised issues that should be considered when planning any future research and development program on broadacre wattle seed production. However, there seemed consensus from the workshop participants that more information is required before any conclusions can be reached on the potential for a wattle seed industry, the likely size of this industry, or its appropriateness for funding under JVAP.

It was determined that a first step will be to investigate the market, in terms of both supply and demand. That is, what food ingredients are likely to be in demand in the future, what is the likely scale of that demand, and can wattle seed, or other *Acacia* products, meet any of these demands. It is not until these issues have been resolved that any intensive breeding or field trials should be undertaken. However, it would be appropriate for some desktop studies in the area of production systems to be ongoing.

6. Conclusions and Recommendations

1. There is not sufficient information currently available to make conclusions about the potential for a broadscale wattle seed or *Acacia* industry. The most limiting factor is knowledge about the nature or size of the markets that wattle seed may be able to supply.
2. Large-scale agroforestry industries are of most interest to JVAP. Until the market prospects for wattle seed are more conclusively addressed, it is difficult to assess whether a wattle seed industry could grow to a broadscale industry.
3. The prospects for a broadscale wattle seed industry need to be assessed further before a decision to support R&D funding from JVAP for developing a wattle seed industry is made. In particular:
 - (a) a balance needs to be developed between developing a wattle seed industry per se, developing an “*Acacia*” industry where wattle seed is viewed as an opportunistic by-product, and other commercial prospects for non-*Acacia* perennial species that address sustainability issues.
 - (b) a decision will need to be made by RIRDC as to whether JVAP, or the sub-program based on bush foods is the most appropriate funding source for R&D.
4. To assist with these decisions, and to further the development of a wattle seed industry, it is recommended that further R&D activity should be undertaken in phases.
5. The first phase should consist of the following research activities:
 - (a) An urgent consideration should be a marketing study that establishes current and future demand for certain food ingredients, including community health needs and diet preferences. A part of this would be the size and value of particular markets that could potentially be serviced by wattle seed eg mung beans, chickpeas etc. Such a study should include not only products from the seed, but also other parts of the tree such as gum exuded from the trunk, the seed pods and the leaves. Both human and animal nutrition markets should be considered.
 - (b) At the same time, an initial scientific analysis of the nutritional and functional constituents of selected species should be undertaken to determine which of the potential markets identified can be serviced by wattle seed or other *Acacia* products.
 - (c) A review of the legislative and regulatory aspects of developing food ingredients will also be essential as part of this first phase of research.
 - (d) In keeping with an integrated systems approach, desk-top research should continue on the nature and economics of potential production systems. Variables to be considered would include establishment, layout, density, plant shape, harvesting mechanism, fertiliser and pest control.
6. Following the completion of these Phase 1 research activities, a decision should be made as to whether further industry development of any type is feasible. If it is determined there is some potential, a decision should be made as to the potential market or markets to be targeted, and the potential size and likely value of these markets. This will determine the nature of any further research, and whether that research is appropriately funded through JVAP or through some other sub-program. It is recommended that breeding or field trials would be delayed until the Phase 1 studies have been completed, and potential target markets have been identified.
7. If appropriate, once the target market(s) has been determined, and if the overall prospects for market penetration and commercial profitability appear favourable, a systems based research program focusing on species selection and breeding for nutritional and growth characteristics should be undertaken. Selection should consider not only the required nutritional characteristics, but also the desired tree shape and water use characteristics. This breeding program should include field trials.
8. Once it has been determined what tree shape is possible within an envisaged production system, a mechanical harvester and planting system should be developed that maximises cost efficiencies,

as well as sustainability benefits. It may be preferable to design the harvester in conjunction with Step 7 above.

Part 2: Invited Papers

Economic Potential for a Wattle Seed Industry

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Introduction

This paper draws heavily on the report titled “Wattle Seed Production in Low Rainfall Areas” (Simpson, S. and Chudleigh, P., June 2001). This report was the result of a desktop study commissioned by RIRDC in late 2000.

The aims of this study were to investigate the potential for broadacre wattle seed production in the medium to low rainfall areas of southern Australia while considering the implications for resource sustainability, and the potential for wattle seed to penetrate large-scale markets.

Information on the following will be presented in this paper:

- the existing and potential markets for wattle seed, along with some nutritional characteristics requiring further investigation;
- factors to consider relating to production systems;
- harvesting options and issues;
- key assumptions and results from the economic analysis conducted for the RIRDC report, along with the key constraints of this analysis; and
- conclusions.

Each of these topics is discussed only briefly, the intention being to provide an overview and context for each of these topics, as they will be focused on in more detail in other papers in these proceedings.

Existing Markets

Currently, the market for wattle seed is almost solely as a bushfood. The seed has been identified as one of the ten most commercially acceptable species of the bushfood industry (Graham and Hart 1998). Total product used by processors in 1995/96 was 6.0 tonnes at a wholesale price of approximately \$30 to \$35 a kilogram for clean, roasted seed, and \$53 to \$59 a kilogram for ground clean roasted seed (Graham and Hart 1998). A separate, more recent estimate is that the current demand for wattle seed is between 12 and 20 tonnes, with a farm-gate price of between \$12 and \$25 per kg of clean seed (Beal, pers comm, 2000). Variables that affect the price include the size of the consignment and the size and quality of the seed.

Existing uses/markets include:

- flavouring agent in confectionery, sauces and ice cream
- coffee substitute
- edible oil
- flour used in biscuits, breads and pasta
- cosmetics including soaps and facial scrubs
- animal and fish feeds

Potential Markets

The existing bush food market is expected to grow modestly over the next decade, particularly if export markets are developed. However, this specialty and novel food market will most probably never reach a scale where broadacre dryland production would be required.

It may be possible to develop other markets for wattle seed, for example in low glycaemic foods and specialty flour markets for bread, biscuits, cakes and pastas. It is possible that only low proportions of wattle seed could be used in breads due to the absence of gluten. Further research is required into the baking characteristics of wattle seed in order to determine the maximum proportion of wattle seed that can be incorporated into breads.

High usage markets such as starches, vegetable proteins or vegetable oils are possible, but would depend on the nutritional characteristics and food processing qualities of the seed, and on being able to be produced at very low cost in order to penetrate and compete in these markets.

While there has been a limited amount of research already completed on the nutritional composition of wattle seed, it is clear that further research is required before any conclusions can be drawn about which markets could be targeted. Examples of key characteristics requiring further investigation include:

- amino acid composition
- protein inhibitors
- isoflavins
- flavour characteristics
- oil and fat composition
- carbohydrates
- soluble fibre
- characteristics of seed coat
- mineral composition

Co-Products

Agroforestry species for low rainfall areas most likely to succeed commercially are those that produce multiple products. Harvesting methods and production systems will be factors in determining multiple product opportunities.

Examples of co-products which may be appropriate for *Acacia* include:

- woodchips for panel board manufacture
- stock fodder (grazed in paddock or modified feed pellets for feedlots)
- bio-energy
- tannins
- firewood
- specialty timbers
- fence posts
- gum arabic
- flowers

Production systems

Production systems will be largely influenced by the harvesting mechanism. Four separate options for the layout of a wattle seed production system have been identified:

- plantation
- rotation (phase) cropping
- alley planting
- companion planting

Layout can be a major influence on the level of water use by the plants.

Establishment of the *Acacias* can be by direct seeding or bare rooted seedlings. Issues related to pests, weeds, disease and fertilisers are comparable to those of other woody native species. Under a rotation cropping system *Acacias* may provide benefits to subsequent crops.

There are over 1000 species of *Acacia* in Australia. Market factors, as well as production factors, will dictate the species type. Important factors to consider are:

- tree form

- toxicity, taste and nutritional characteristics
- adaptability to various climates and landscapes
- growth characteristics (eg speed)
- seed characteristics (eg size of seed crop, reliability, harvest window)
- ease of propagation and establishment
- pruning, shaping and coppicing

Harvesting

Currently, most wattle seed supplying the bush foods market is harvested from natural stands. This wild harvesting is generally effected by hand and is very labour intensive. The development of an efficient and economic harvester for extensive wattle seed production from plantations is one of the key constraints to achieving a low production cost of seed and a large portion of the R&D required in regards to wattle seed production will need to be aimed at reducing the cost of harvesting.

Three possible harvesting options have been identified:

1. 'Butt-shaking': An arm grabs the main stem (butt) of the tree and shakes, causing the seeds and pods to fall off. The *Acacia* seeds and pods are then collected in a metal tray that surrounds the tree.
2. 'Fingers': A mechanical shaker which works by brushing plastic fingers through the outer foliage. This would be in the form of a stripper harvester that would have brushing fingers with keyholes to strip the pods. For this type of system to be successful however, the seed pods would need to be at the extremities of the bush and the bush would need to contain little heavy wood (maximum 15mm diameter).
3. Biomass harvest: Refers to harvesting by removing the entire above-ground biomass and then allowing coppicing. This would involve harvesting both seed and biomass once every four years or so by cutting back the tree to a stump and then allowing it to regenerate.

The major factors regarding the success and economic feasibility of harvesting *Acacia* seed relate to:

- the shape and silviculture properties of the species chosen
- the length of the available harvest window
- the harvesting method and its interaction within the production system with average yield per annum
- the potential for harvesting and utilising co-products

Sustainability

At the time of the study, little or no research had been done into the rate of water use of *Acacia* species, and their likely success in reducing the level of the water table. The commercial benefits of wattle seed should be considered in comparison to other perennials and potential agroforestry species, which also have the potential to lower the water table.

Olsen (pers comm, 2000) suggests that the level of water use of *Acacias* will be dependent on many factors, including the growth rate of the plant, the plant spacing, frequency of harvest, amount of foliage growth between harvests, and a range of environmental factors (eg. rainfall, soil type, depth of unsaturated zone, availability of fresh groundwater).

Benefit-Cost Analysis

Benefit-cost analysis is an effective way of summarising and interpreting assumptions. Please note that these assumptions are indicative only and further work is required in order to confirm or identify more accurate parameters.

It is assumed that the budget for wattle seed developed refers to a current farming operation wishing to move part of the farm from, for example, wheat production into wattle seed production. Therefore all fixed costs are ignored. This is important as the results therefore are not indicative for someone wishing to buy land and equipment and develop a wattle seed enterprise. Also, the cost of wheat production foregone has not been included.

Investment analyses were carried out for each of the three separate harvesting scenarios identified. Table 1 presents a summary of the assumptions used in the benefit-cost analysis.

Table 1: Summary of Assumptions Used in Benefit-Cost Analysis

Item	Harvesting method		
	Scenario 1: Shaking	Scenario 2: Fingers	Scenario 3: Biomass harvest
Discount Rate	10%	10%	10%
Longevity of trees	12 years	12 years	12 years
Density under plantation conditions (a)	625 trees/ha	625 trees/ha	625 trees/ha
Cost of plant material (b)	\$300/ha	\$300/ha	\$300/ha
Ground preparation and direct seeding (c)	\$80/ha	\$80/ha	\$80/ha
Pruning and training (d)	\$0/ha	\$0/ha	\$0/ha
Pesticide and fertiliser application (d)	\$0/ha	\$0/ha	\$0/ha
Harvesting cost (e)	\$3125/ha	\$750/ha	\$500/ha
Farm-gate price for wattle seed	\$1/kg	\$1/kg	\$1/kg
Marketable yield per plant at full production (f)	2kg per tree	2kg per tree	2kg per tree
Year of first harvest (g)	Year 3	Year 3	Year 4
Yield per plant (% of full production)			
Year 1	0%	0%	0%
Year 2	0%	0%	0%
Year 3	50%	50%	0%
Year 4	85%	85%	85%
Year 5	95%	95%	0%
Year 6	100%	100%	0%
Year 7	100%	100%	0%
Year 8	100%	100%	85%
Year 9	100%	100%	0%
Year 10	100%	100%	0%
Year 11	85%	85%	0%
Year 12	85%	85%	85%
Growth rate of biomass (h)	5m ³ /ha/year	5m ³ /ha/year	5m ³ /ha/year
Value of biomass (h)	\$10 / m ³	\$10 / m ³	\$10 / m ³

Explanatory notes for Table 5.1:

- (a) It is reported in Graham and Hart (1998) that the plant density for wattle seed is 625 plants per hectare. It is not specified whether this density relates to dryland or irrigated systems. Beal (pers comm, 2000) indicates the plant density under irrigated conditions is 667 plants per hectare.
- (b) The cost of seed for one hectare was calculated by making assumptions about the survival rate, quantity of seed per kg, and the price per kg of seed. It is assumed there are approximately 20,000 seeds per kg, that the average survival rate is 0.1%, and that the cost of seed is \$10/kg.
- (c) Ground preparation and direct seeding cost were estimated at approximately \$80/ha, based on 2 hours/ha operating time for ground preparation and 2 hours/ha for direct seeding, with each activity requiring one labour unit at \$10/hour (\$40) plus an equivalent amount (\$40) for fuel and maintenance.
- (d) These two variables are assumed at zero cost for the purposes of the basic analysis. It should be noted however that these inputs may be necessary.
- (e) The harvesting cost for Scenario 1 (Shaking) is based on the following assumptions. Assuming the machine can be adequately utilised throughout the year in different regions, then the hourly cost of using the harvester can be assumed to be \$100/hour. This is inclusive of labour, fuel, maintenance, capital depreciation etc. It is further assumed that the harvester can harvest 20 trees per hour. Therefore, the harvester would take 31.25 hours to harvest one hectare containing

625 trees, at a cost of \$3125 per hectare. At full yield production of 2 kg per tree, this equates to harvesting 40 kg per hour, at a cost of \$2.50 per kg.

The harvesting cost for Scenario 2 (fingers) is based on the assumption that as this is a similar harvesting method to coffee harvesting, the harvesting cost can be assumed to be roughly similar, at \$750 per hectare.

The harvesting cost for Scenario 3 (biomass harvest) is based on that for tea tree oil, but allowing for the reduced amount of biomass for *Acacias*. However, *Acacia* harvesting will incur the additional cost of separating the wattle seed from the biomass.

- (f) Graham and Hart (1998) state that the average yield is 1.5 kg per plant. Maslin et al (1998) quote slightly higher potential yield figures of 2 kg of seed per plant. It is assumed that both of these figures relate to yields being observed on natural stands of *Acacias*. Therefore, it is assumed that with appropriate selection of seeds from plants and varieties known to be high yielding, a marketable yield of 2 kg per tree with 625 trees per hectare, in a year of average rainfall could be expected.
- (g) The year of first harvest could vary depending on the economics of the level of yield, price and harvest cost in a given year. Yield distribution by year will depend on species type, as well as other variables (e.g. rainfall, soil type)
- (h) The growth rate of biomass is based on that reported for Eucalyptus species in Zorzetto and Chudleigh (1999). Also adapted from this publication, is an approximate price per wet tonne of biomass (one wet tonne is assumed to be equivalent to 1m³) for *Acacia* species.

Results of the investment analysis are presented in Table 2.

Table 2: Base Results for Benefit-Cost Analysis
(for 1 hectare, over 12 years, at a 10% discount rate)

Investment Criteria	Scenario 1: Shaking	Scenario 2: Fingers	Scenario 3: Biomass harvest
Net Present Value (\$)	-11,481	1,785	851
Benefit/Cost ratio	0.4 to 1	1.4 to 1	2 to 1
Internal Rate of Return (%)	no solution	45	39

The results show that production under Scenario 1 (harvest by ‘butt-shaking’), is not economically viable unless the cost of harvesting can be reduced to \$1070 per hectare, or if the yield and/or farm-gate price can be significantly increased. It may only be appropriate for this harvesting method to be used to service the bushfood or other niche industries, where a premium price for wattle seed can be attained and where other harvesting methods have not been developed.

Scenarios 2 (harvest by ‘fingers’) and 3 (biomass harvest) both show promise of being economically viable, and at appropriate yields, able to remain economically viable at a farm-gate price of less than \$1/kg.

From sensitivity analyses conducted it is evident that there are three key drivers of the economic viability of wattle seed production.

- harvesting method and cost
- yield, and
- farm-gate price

Potential sustainability benefits were not quantified in the analysis.

The preliminary feasibility study suggests that the idea of large scale production of wattle seed is worth pursuing further. However, it is apparent that before any position on the viability of wattle seed production is adopted, a significant amount of further information needs to be assembled.

Information needs are divided into four separate categories:

- Food processing and nutritional characteristics of wattle seed;
- Production systems, species selection and harvesting;
- Sustainability; and

- Economic and market analyses

Conclusions

The following conclusions have been drawn:

- It may be possible to develop niche or intermediate markets for wattle seed (eg increased bushfood demand, low glycaemic, specialty flours, oils). High volume markets such as starches, vegetable proteins etc would also be possible but would depend on seed being able to be produced at very low cost, for example significantly less than \$1 per kg. It may also depend on some unique properties being discovered to ensure wattle seed is competitive.
- Interactions with harvesting, species selection and co-products are very important when considering characteristics of production systems such as layout.
- Wattle seed production could contribute to increased water use over annual crops and pastures. However the extent of such contribution to lowering groundwater tables and reducing the impact of salinity has not been quantified.
- Harvesting is a key cost component and a significant driver of the economics of wattle seed production. There are several harvesting options that can be explored.
- The three key drivers of the economic viability of wattle seed production are the harvesting method and subsequent cost, the yield and the farm-gate price. Scenarios 2 and 3 both show promise of being economically viable, however it is stressed again that the assumptions used in this analysis are indicative only, and further work is required in order to confirm or identify more accurate parameters.

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Building a Large-Scale Wattle Industry

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Abstract

A large-scale wattle seed industry, based on suitable species in the *Acacia* genus, could provide substantial land management benefits in dryland agricultural areas in southern Australia. This paper discusses market opportunities for wattle seed, and some production issues that determine its potential profitability.

Wattle seed could be sold in a number of different sized markets, ranging from niche markets for bushfood and other specialty uses, to small to medium-sized markets for nuts, snack foods and pulses, and large markets for staple grains, oilseeds, food ingredients and stockfeed. At each step up in market size there is a corresponding step down in market price.

Major Australian grain and seed crops such as wheat, barley and canola are produced at very low cost in highly mechanised, extensive farming systems. These industries are under constant pressure to maximise yield, improve quality, minimise costs, and export most of their output into competitive global markets. A large-scale wattle seed industry would be subject to the same pressures.

The existing wattle seed industry is very small. It is based on tall shrub and tree *Acacia* species with a long history of traditional use as food by Australian Aborigines, and includes both wild harvesting and small-scale cultivation. Scaling up production will involve a change in methods, including the development of mechanised harvesting.

The development of row-crop harvesters should bring significant reductions to harvesting costs for the wattle seed species in current use. This harvester development path could suit a small to medium-sized industry based on high value seed, but it will reach its limits long before becoming competitive with broad acre grain production systems harvested by headers.

A more promising development pathway for large-scale crops is to develop a wattle crop with a different morphology – one that has many features in common with broad acre crops, enabling it to be grown in paddock layouts, and to be harvested by equipment with similar efficiency to conventional grain harvesters. Desirable features in the plant include short stature, reasonably erect form, high ratio of seed production to vegetative growth, formation of pods and seeds at or near the top of the plant, large seed size, synchronous seed ripening, and reduced or inhibited pod shattering.

When developing a new crop, it is important that key aspects of farming system design are considered simultaneously. Important issues for wattle seed development are species selection, crop design, management methods and harvester development.

At a broader level, requirements for new crop development include:

- suitable germplasm
- efficient, integrated farming systems
- appropriate growing, harvesting and processing technology
- acceptable product quality
- market penetration

Does wattle seed have the potential to become a major food crop? It's too early to say, but further investigation is warranted. *Acacia* is an extremely diverse genus, with about 1,000 different taxa identified in Australia. A proper investigation of this variability may find suitable species or populations from which successful new crops can be developed.

In conclusion, it seems likely that further development of existing tall wattle seed species and associated harvesting technology will enable the industry to grow from a niche industry to a small industry, but this pathway will not lead to the development of a large industry. To achieve that goal, and its associated land management benefits, a different development path is needed – one that selects and develops new germplasm better suited to efficient management and handling.

Introduction

The extensive development of dryland salinity in cleared agricultural areas in southern Australia demonstrates the unsustainable nature of current agricultural practices based on annual crops and pastures. Treating the source of the problem, by reducing the amount of rainfall that drains into the soil below the root zone (recharge) is one treatment option.

Perennial crops could reduce recharge, and simultaneously address other aspects of agricultural land management such as erosion control and soil structure decline. To be effective in salinity management, perennial crops would need to be implemented on a large scale, with a leaf area index approaching that of the original native woodland (Hatton and Nulsen 1999). There are a number of hurdles to be overcome to achieve such a target, including:

- Growing perennial plants extensively at the same low productivity as the original native woodland is clearly not a commercial option. A more promising approach is to design intensive arrangements of high productivity perennial crops, to produce the required leaf area (and water use), while leaving space for other agricultural crops. Alley farming layouts based on wide-spaced belts of short-rotation perennial plants, and phase farming in which a short, periodic perennial plant phase is incorporated into the sequence of annual cropping, are two such designs (Bartle 2001; Harper et al. 2000).
- Finding markets large enough to absorb the amount of produce that large areas of new perennial crops would produce will be challenging (Bartle 2001). For example, ten million hectares of new, woody perennial crops (approximately 20% of the agricultural area in southern Australia's low and medium rainfall zone) could produce 75 million dry tonnes of above-ground biomass per year - more than ten times Australia's woodchip exports. If the crops produced commercial seed, then some 10 million tonnes could be produced each year – a new industry half the size of the Australian wheat industry.

Native plant species in the large and diverse *Acacia* genus are being investigated for their potential to produce commercial products. There is a wide genetic base to choose from - approximately 1,000 *Acacia* species are found in Australia. Of those, approximately 350 are found in the temperate dry zone, which includes much of the dryland agricultural areas of southern Australia (Maslin et al. 1998). Potential large-scale uses include paper, panel board and bioenergy production, while smaller scale products could include fodder, tannins, gums and edible wattle seeds.

Wattle seed is of particular interest because there is an existing, but very small wattle seed industry that could provide the foundation for a larger industry in future. The interesting question from a land management perspective is: What scale of wattle seed production is feasible?

This paper reviews the market options for wattle seed, and discusses their implications for crop development.

Current wattle seed industry

At present, wattle seed is sold in very small quantities into niche food markets, mostly marketed as 'bushfood'. The Australian market is estimated to be 12 to 20 tonnes per year, with farm gate prices of \$12 to \$25 per kg for clean seed (Simpson and Chudleigh 2001). Production methods are high-cost, with most seed harvested manually from natural stands. A few private growers harvest seed from small plantations, and a start has been made to improve production efficiency.

Potential markets for wattle seed

Maslin *et al.* (1998) describe seventeen species with potential for seed production, and list several food and industrial uses with potential to expand the industry - flavouring in confectionery, sauces, seasoning, cream and ice-cream; flour in biscuits, bread and pasta; coffee substitute; edible oil; cosmetics such as soaps and facial scrubs; and animal and fish feeds.

Future opportunities discussed in Simpson and Chudleigh (2001) include small markets such as bushfoods and low glycaemic foods, medium-sized markets for flour, and large markets for generic food ingredients such as starch, oil and protein.

The nature of any future wattle seed industry will depend largely on the scale of production and the size of target markets. For example, species selection, production methods, and marketing requirements are likely to be quite different for an industry providing high-volume, low-value seed for commodity food markets, compared to an industry supplying small markets for low-volume, high-value specialty foods.

Various different markets for wattle seed are discussed below. In each case it is assumed that wattle seed is suitable for the proposed end use, and that issues of nutrition, food safety and regulatory approval have been resolved.

Table 1 contains a summary of features commonly found in food markets of various size. Three different market sizes are considered:

- niche markets for high-priced specialty products
- small to medium-sized markets for specific grains and seeds
- large volume, low value markets for generic food ingredients and stock feed

Table 1: Features of different sized markets for perennial crops

	Market size		
	Niche	Small to medium	Large
Price received by growers	High	Moderate	Low
Relative importance of product's price	Low	Moderate	High
Relative importance of marketing strategy	High	Moderate	Low
Potential for value adding by growers	High	Moderate	Low
Scale of land management benefit	Farm scale	District or sub-catchment	Catchment or larger
Justification for public investment	Low	Moderate	High

Niche markets

Wattle seed can be marketed in domestic and global niche markets on its novelty value ('bushfood'), or for its special taste ('nutty') or special nutritional characteristics (gluten-free, caffeine-free, low glycaemic index). These markets could grow substantially from their current low level, and sustain an industry based on high-cost, horticultural production methods. Increasing wealth in the developed world, and in many developing countries offers a diversity of market opportunities, although many of these could be short-lived, as they are subject to changes in fashion, and changes in public perception of nutritional issues.

However, even if wattle seed were to become successful in a large number of niche markets, the industry would remain small, perhaps one to two thousand hectares, and the environmental benefits produced would be localised, farm-scale benefits for participating growers.

On the positive side, success in niche markets depends heavily on marketing skills rather than the price of the product, so a niche industry that is well managed, and promoted effectively, can be very profitable for its participants. This scale of industry provides excellent opportunities for private investment and privately controlled industry research and development.

Small to medium-sized markets

Markets for nuts, grains and seeds include higher priced segments where the product is served as a clearly identifiable food item, plus lower value uses in confectionery, garnishes and flavouring. These markets are attractive due to their moderate size, and moderately high prices. Three market segments are considered below – tree nuts, snack foods and confectionery, and pulses.

Tree nuts

The Australian market for tree nuts is quite small, with annual consumption of about 24,000 tonnes of shelled nuts. International trade (on a shelled basis) is 1.1 million tonnes per year – mainly cashews, almonds and hazel nuts. Average global export prices for shelled nuts vary from less than A\$4,000 per tonne for chestnuts, to more than A\$10,000 per tonne for macadamia nuts and pistachios (FAO 2002).

If wattle seed supplied 10% of the Australian tree nut market, only a few thousand tonnes of wattle seed would be required per year. The global market is much larger - a 1% share of global imports would consume about 10,000 tonnes of wattle seed, and support a small industry of 10,000 hectares of trees. However, it is hard to see wattle seed capturing very much of the high value market for tree nuts, given the strong market position of existing nut types, and the different shape, size and flavour of wattle seeds.

Snack foods and confectionery

An easier target for wattle seed could be the lower-priced portion of the snack food market. The combined Australian market for peanuts, sesame seeds and sunflower seeds used in snacks and confectionery is small – perhaps 25,000 tonnes per year. Global markets are more substantial – total world imports are 1.3 million tonnes of peanut kernels at A\$1,200 per tonne, 0.6 million tonnes of sesame seed at A\$1,300 per tonne, and 4 million tonnes of sunflower seed at A\$450 per tonne (FAO 2002). Note that only a small percentage of sunflower seed is used in confectionery – most is used for oil production.

If wattle seed were to supply 10% of the Australian markets for snack food and confectionery grade peanuts, sesame seeds and sunflower seeds, a small industry of 2-3,000 hectares would suffice, while capture of 1% of global imports of the same products could possibly support an industry of 20-30,000 hectares. If prices greater than \$1,000 per tonne could be achieved, these markets could be profitable for growers using horticultural production methods.

Pulses

Because of the small Australian population, and the low usage of dry beans in Australian cuisine, it is likely that a medium-sized wattle seed industry would need to export most of its produce in this market category. Already, almost 75% of Australia's annual production of 880,000 tonnes of dry peas and beans, chickpeas and lentils is exported (FAO 2002). Although global trade volumes for these foods are an order of magnitude larger than trade in nuts, export prices are an order of magnitude lower. For example, global exports total 7.5 million tonnes per year, at prices between \$300 per tonne and \$700 per tonne. Details for individual crops are shown in Table 2.

Of the various pulse markets, many are likely to be out of reach of wattle seed growers because of their low export price. Most pulses sell for well below A\$500 per tonne in international markets. Two

exceptions are dry beans and lentils, but both are small industries in Australia, with a combined annual production of about 110,000 tonnes. However, their combined global trade is approximately 3.3 million tonnes per year. If wattle seed could capture 2% of these markets, then a moderate sized industry of more than 50,000 hectares could be supported.

Table 2: Production and trade data for pulses

Crop	Global trade (million t)¹	Australian production (t)	% exported	% of global trade	Australian export price (A\$)
Dry peas	3.23	405 000	61	8	301
Broad beans	0.43	144 000	87	29	349
Chick peas	0.60	225 000	91	34	442
Lentils	0.84	66 000	41	3	573
Dry beans	2.42	41 000	95	2	671
Total	7.52	881 000	73	9	395

¹ Includes internal European Union trade.

All data are 1995-2000 averages (FAO 2002)

Prospects – small to medium-sized markets

To capture part of the small, high-value export markets for nuts and snack food components, and the larger, but lower-valued markets for pulses would require changes in tastes and habits by consumers, a process that is likely to be both slow and difficult. Moving wattle seed beyond being a curiosity food into the mainstream would require sustained, effective, and culturally specific marketing campaigns in a range of target markets, in direct competition with a diverse range of well-established, popular foods.

Price becomes important in these markets. Large sections of the pulse market are already too low-priced for wattle seed produced using horticultural methods.

Assuming that wattle seed were successful in expanding into these small and medium-sized markets, the likely size of a wattle seed industry could be in the thousands, or even tens of thousands of hectares. A perennial plant industry of this size could provide significant land management benefits on a sub-catchment scale, and could attract some public investment in its development.

Large markets

Potential large markets for wattle seed include staple grains, food ingredients and stockfeed. Price, quality, compatibility with processing requirements and reliability are the main determinants of success in these markets.

Production and trade figures for the major Australian dryland grain crops are given in Table 3.

Staple food grains

The most important food grains are wheat, maize and rice – each has global production rates of almost 600 million tonnes per year. Wheat is the most traded, with 19% of global production being exported, compared with 13% for maize (including a large stockfeed component), and 4% for rice (FAO 2002).

Wattle seed would be expected to face considerable initial resistance in the grains market, both in Australia and from importing countries accustomed to particular grains in their diet, as it is not sufficiently similar to other grains to be a direct substitute. Campaigns would be needed to educate consumers on appropriate ways to use wattle seed in food dishes and baking products.

Generic food ingredients

For generic food ingredients such as starch, protein and oil, the nutrition and processing characteristics of wattle seed, and their uniformity, are more important than aesthetic considerations, as most of these products are used in processed foods where they are blended with ingredients from other sources, and then disguised by various additives (colours, flavours, thickeners, emulsifiers, etc.).

Wattle seed is similar to other legumes in terms of protein and starch content. Tests carried out on 58 samples representing 26 species gave average results of 23% crude protein and 26% available carbohydrate (Brand and Maggiore 1992; cited in Maslin et al. 1998). The oil content of wattle seed is higher than in most legumes, with most of the oil being unsaturated (Brand and Maggiore 1992; cited in Simpson and Chudleigh 2001).

Stock feed

Stockfeed, an indirect human food market, is a relatively indiscriminating market. A share could be captured by wattle seed if it could be produced with an attractive combination of price and nutritional value. Asian markets are a potential target for Australian producers, although there has been little growth in Asian imports of Australian feed grains over the past decade. However, almost half of the expected growth in demand for coarse grains in the next three decades will be for stockfeed (FAO 2000), so this segment of the market offers growth potential for Australian farmers. Strong competition can be expected from well-established, high quality stockfeed such as maize.

Market prospects – large markets

There has been little or no growth in prices for grains, seeds and pulses over the last two decades, and in some cases price declines (ABARE 2001).

Given the slowing rate of population growth (United Nations 2001), surplus global capacity in food production, and increasing food saturation of most of the world's population, demand for food is expected to grow more slowly than increases in agricultural production during the next 30 years (FAO 2000). As a result, grain markets are likely to remain very competitive, with continuing pressure on prices in most years. No real increase in grain prices is forecast for the coming decade (World Bank 2002).

Developing a new large-scale seed industry in this economic environment will be very difficult. However, if wattle seed can capture a significant share of any of these major markets, an industry measured in hundreds of thousands of hectares, or perhaps even millions of hectares could result, providing correspondingly large, catchment-scale land management benefits. A new industry at this scale would be likely to attract significant public investment in its development.

Of the three large market segments described, generic food ingredients and stockfeed would be the easiest for wattle seed to expand into because the criteria for success are technical in nature, such as nutritional content and compatibility with manufacturing processes. However, they are the most demanding on price, and are extremely competitive markets. Staple food grains for human consumption attract higher prices but must meet the expectations of human consumers – a more challenging marketing task.

Table 3: Production and trade tonnages for major dryland food crops

Crop	Australian production (Mt)	Australian exports (Mt)	Global production (Mt)	Global exports (Mt)	Global export price (A\$)
Wheat	21.66	15.21	583.9	108.0	221
Barley	5.94	3.25	141.5	21.3	193
Oats	1.56	0.17	28.0	2.5	179
Lupins	1.52	0.75	1.7	0.8	224
Canola	1.30	0.79	36.5	7.9	381
Triticale	0.59	0.00	8.6	0.1	243

Note: Global export figures include internal EU trade.

All data are 1995-2000 averages (FAO 2002).

Using other grain and seed crops as a yardstick

Of the many dryland crops grown in southern Australia, only five produce more than one million tonnes per year – wheat, barley, oats, lupins and canola – and over 60% of their combined output is exported. Average crop yields are between 1 and 2 tonnes per hectare, and average prices received by growers range from \$110 per tonne for oats to \$340 per tonne for canola (ABARE 2001).

Production costs are very low due to the large size of most farms, and the extensive, low input farming methods used. For example wheat costs about \$110 per hectare to grow and \$30 per hectare to harvest (approximate contract costs for a 1.7 tonne per hectare crop on a Western Australian wheatbelt farm, excluding overheads and GST).

For wattle seed to become a perennial crop large enough to produce significant salinity benefits, it would need to become one of Australia's major grain and seed producing industries. It would face the same pressures as other major crops to continually improve its production efficiency – to maximise yield, improve quality, and reduce costs – and it would need to conform to a similar production pattern, involving:

- low cost production in highly mechanised, extensive, low yielding dryland farming systems, and
- export of a large proportion of its output into fiercely competitive global markets that are distorted by heavily subsidised produce from the USA and Europe.

Limitations of current wattle seed production systems

Australian farmers produce millions of tonnes of wheat, barley, canola, oats and lupins, two thirds of which are sold into large global markets for a few hundred dollars per tonne. The current wattle seed industry is at the opposite end of the spectrum - wattle seed is sold for \$10,000 per tonne or more, in very small quantities in local niche markets.

The wattle seed industry is slowly expanding from a wild harvest operation into a horticulture venture, based on tall *Acacia* species with a long history of use for edible seed. Future improvements in growing methods and harvesting technology are expected to lower wattle seed production costs significantly, and enable it to be sold into a wider range of markets.

Some elements of low cost production are easily achievable. Direct seeding should be easily handled by conventional seeding equipment, and bulk handling of wattle seeds should present few problems to existing grain industry infrastructure.

Little work has been done so far on germplasm selection, silvicultural practices, and the development of mechanical harvesting, so progress in each of those areas is likely to provide significant improvements in production efficiency. However, the cost of production of seed from tall *Acacia* species grown using horticultural methods, no matter how refined they become, is unlikely ever to be competitive with the cost of production achieved in large-scale annual cropping, due mainly to the difficulty of harvesting seeds from tall shrubs and trees.

High cost harvesting

A major stumbling block for the current wattle seed industry is the cost of harvesting. Various methods have been proposed to mechanise the process of pod or seed removal, including shaking each tree's trunk, beating the foliage, combing the foliage with mechanical fingers, and harvesting whole biomass and separating the seed after harvest. The cost of each of these techniques is estimated in a recent review (Simpson and Chudleigh 2001). Not surprisingly, trunk shaking was the most expensive method at over \$2,500 per tonne, while combing with mechanical fingers and whole biomass harvesting, both of which can be carried out using continuously moving machines, were estimated to be much cheaper at \$600 and \$400 per tonne respectively. Even allowing for large cost reductions as these methods are developed and refined, they are unlikely to achieve harvesting costs similar to the \$20 per tonne commonly found in annual cropping.

One impediment to efficiency in harvesting traditional wattle seed species is their tall non-uniform shape. The most promising option for harvesting plants of this shape would be a continuously travelling machine that either travelled between rows, harvesting seed from the plants on both sides as it travelled, or else travelled over the top of each row of plants, removing seeds from both sides as it straddled them. In both cases, there would be a trade-off between ground speed and percentage of seed harvested from each plant. Thoroughness and finesse would decline as ground speed increased – more seed would be likely to escape being beaten or frisked, and more would be likely to fall to the ground without being caught.

Optimising harvesting efficiency

Harvesting efficiency is not optimised in a vacuum. It is also affected by the species being grown, and the layout and silvicultural practices employed. These additional three elements of the production system need to be considered simultaneously.

For example, in a system using a continuous harvester travelling between rows of *Acacia* trees, simultaneously harvesting seed from trees on both sides, factors that need to be integrated in order to optimise the whole system, include:

- row spacing matched to harvester width,
- spacing between trees (within rows) optimised for a combination of harvesting efficiency, and tree productivity (to minimise competition for resources, but maximise resource capture),
- preference for species bearing most seed on the sides of the tree,
- trees pruned if necessary to maintain uniformity, and keep seed bearing branches within reach of the harvester,
- rows oriented to avoid adverse effects (if any) from excessive shading.

If instead, a harvester were designed to collect seed from only one side at a time, or if it straddled each row of trees and removed seed from both sides of the row simultaneously, then a different set of constraints on species selection, layout and silviculture would apply.

In all systems, the productivity of harvesting is likely to be increased by improving the shape of the plant, either by pruning, or by plant breeding.

Pathway to a low-cost wattle seed industry

In a previous section, we saw that each large step up in market size for edible seeds and grains is accompanied by a large step down in price. It seems likely that the integrated production system that is optimal for one industry size would have a quite different combination of species, layout, silviculture and harvesting technology from the production system best suited to a different sized industry.

Therefore, if the aim is to develop a large-scale wattle seed industry, simply scaling up a small existing industry may not be the best pathway. For example, the development of efficient, continuously travelling row-crop harvesters would bring significant reductions to harvesting costs for the wattle species currently used to produce seed, and would suit a small to medium-sized industry based on high value seed. However, it is very unlikely to lead to a harvesting system that is

competitive with broad acre systems based on headers. A better approach is to start from first principles and consider all the elements required for a low-cost, large-scale industry.

Interrelated conditions that need to be satisfied to develop a large-scale edible seed crop include:

- suitable germplasm selection and development
- appropriate growing, harvesting and processing technology
- efficient, integrated farming systems
- adequate product quality, including acceptance as a safe food
- market penetration

Using this approach, a suitable production system for the southern wheatbelt is likely to have the following features:

Crop layout

Dispersed layouts (either spatially or temporally) would be preferred to maximise productivity and minimise drought risk. Plants could be arranged in belts in an alley farming system, or across the whole paddock for a short period of three to five years (phase farming). Plants would need to be short enough to be straddled by a harvester. Where plants were to be grown in belts, belt widths should be either a single harvester width, or a multiple of the harvester width, to ensure the harvester operates at its design capacity.

Harvesting method

Because wattle seed is a low yielding crop (perhaps 1.25 tonnes per hectare), the harvester would have similar design principles to a cereal header – high ground speed, high manoeuvrability, and a wide front. It would straddle the crop, move continuously, and remove only pods and seed if possible.

Species selection

Species suited to the harvesting method described above would be very different from the *Acacia* species currently used for wattle seed production. Attributes they would be likely to possess include:

- uniform height and shape
- short, erect stature
- pods located at or near the top of the plant
- high seed production per hectare (not necessarily per plant)
- high ratio of seed production to vegetative growth
- large seeds
- uniform ripening
- inhibited pod shattering

Other attributes, unrelated to harvesting, to consider during species selection include onset of seeding at a young age (essential for phase farming), resistance to pests and diseases, tolerance of environmental stress, suitable root architecture to maximise exploitation of soil water, desirable nutritional and food processing characteristics, plus factors related to management in a farming system, such as palatability to stock, toxicity to stock, weed risk, nitrogen fixing ability, and tolerance of herbicides and insecticides.

Simultaneous production of biomass and seed

The possibility of producing both edible seed crops and biomass for industrial use is attractive, and is one way of bringing down the cost of harvesting – assuming the seed can be separated efficiently from the harvested biomass. However, there are a number of issues that reduce the feasibility of this option:

- it would be difficult to design a harvester that did both jobs efficiently - biomass harvesting requires a more powerful and robust machine than seed harvesting,
- biomass industries usually require continuous feedstock supply, not just at seeding time

However, if *Acacia* crops are developed for industrial uses, and their seed is suitable for use as food, then opportunistic collection of seed is possible. Seed would be collected during biomass harvesting at seeding time, and could be separated and sold as a by-product.

Conclusion

Further development of existing tall *Acacia* species and associated harvesting technology could enable the wattle seed industry to grow from a niche industry to a small industry, but this pathway will not lead to the development of a large industry. To achieve that goal, and its associated land management benefits, a different development path is needed – one that selects and develops new germplasm better suited to efficient management and handling.

Key steps in developing a large wattle seed industry would be to:

- search the *Acacia* flora of Australia for species that have desirable characteristics for large-scale, low-cost cropping systems,
- explore their potential for improvement by careful selection and breeding,
- integrate species selection, farming system development, and harvester development, to optimise all three simultaneously.

Is this just a dream? Perhaps, but further investigation is warranted. *Acacia* is an extremely diverse genus, with about 1,000 different taxa identified in Australia, and much variation within some of those taxa. An investigation of Australian acacias would be likely to find a number with suitable morphology and growth habit, and sufficient genetic variability to encourage plant breeders to attempt to enhance their desirable characteristics and reduce their weaknesses. There may be scope for more radical genetic intervention to speed up the process.

However, an exploration of the *Acacia* flora is only the first step. New crop development requires substantial investment of time, money and expertise to produce a pool of genetic material with desirable characteristics.

It is unrealistic to expect wattle seed to become a major new crop overnight. All the major agricultural crops have undergone unconscious selection, leading up to their domestication, long periods of informal development since first domesticated (Diamond 1998), and formal plant breeding in more recent times, to produce crops that are easy and reliable to establish and grow, easy to harvest, have high yields, and produce high quality uniform products. The domestication of wild *Acacia* species would require many of the same steps, but could take advantage of modern techniques for genetic investigation and plant breeding to hasten the process.

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The Opportunities for a Cultivated *Acacia* Industry

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Background

Australia's rural economic, ecological and social strategies helped convert a distant penal colony into one of the world's richest countries. These strategies are proving unsustainable over the long term, however, and to remain a rich country Australia needs to develop new rural land uses.

This note discusses one candidate strategy: growing *Acacias* for human food, through wattle seed production.

Australian Native Produce Industries (ANPI), the leading firm in commercialising native food plants, has committed human and financial capital to developing the wattle seed industry. ANPI intends to build a public/private consortium to conduct initial R&D.

The Economic Story

Rural Australia has traditionally relied on commodity production, with emphasis on grains, particularly wheat and livestock, in particular sheep and cattle. These commodities have steadily lost value in real and relative terms for the last 150 years. Australia's farmers have compensated for price reductions by increasing productivity. In the past century, for example, the average yield from a hectare planted in wheat has quadrupled. To some extent farmers and graziers have also compensated by producing higher quality products. Modern wheat, wool, and other commodity products are all superior to the equivalent nineteenth century products.

In the last 50 years in particular, Australia has invested heavily in irrigated agriculture, most notably cotton, grapes/wine, and other horticultural products. This irrigated production is approximately 20 times more valuable on a per hectare basis than dryland production, but requires much more capital, management, and reliable and high quality water supplies.

With significant local exceptions, dryland farming is now unable to compete for new capital and talent against urban industries. The returns to farming are insufficient compared to more knowledge intensive investment opportunities, and the return to human capital is low as well. As a result, our dryland farmers are becoming older and fewer over time.

Irrigation based industries, again with significant local exceptions, are doing well economically, but represent only 2% of land in production.

The Environmental Story

Australia's soils are unsuited to long term production using northern hemisphere derived agricultural methods. We now know that these methods are extractive rather than sustainable industries. In particular, Australia faces a soil quality problem, which in turn leads to a water quality problem.

Our soil quality challenges include dryland and irrigation salinity, wind and water erosion, compaction, nutrient and carbon loss, and microbial loss. Dryland salinity is becoming a particularly acute problem in large areas within the southern agricultural zone.

Water quality degradation results from salt and chemical runoff, as well as subsurface salt moving into our streams and rivers.

Over the next 50 years, Australia is at risk of losing as much as one third of its "improved" agricultural land to soil quality problems. The land most at risk lies in the local low spots; these tend

to be the most productive and profitable agricultural land, high value wetland/biodiversity sites, or townsites and rail/road links.

As water salinity increases and quality declines, our profitable irrigated industries will become increasingly constrained as well, and in some areas may no longer prove viable.

These environmental problems will impair not only direct agricultural production but follow-on industries, notably wine, processed foods, and rural tourism.

The Social Story

Steadily improving productivity is a good economic strategy, but leads to steady depopulation in the country. Much of inland rural Australia, away from the relatively small irrigation districts, is in steady demographic decline. This decline may accelerate as soil quality and other ecological problems become larger constraints on production.

The currently thriving (in general) irrigated centres are at risk from salinity in particular, and must manage this issue if they are to avoid social decline.

What Are *Acacias*?

Acacias (wattles) are distributed throughout Australia, with approximately 900 species identified to date. *Acacias* are perennial woody large shrubs or small trees, and they are leguminous (nitrogen fixing). In the wild, *Acacias* are usually pioneer species, re-establishing first in disturbed soils.

There is considerable diversity among *Acacia* species. High potential candidate species will be selected for edible seed production, three to five meter height (to simplify harvesting), and environmental sustainability in commercial cultivation. We have identified approximately 10 candidate species to date.

***Acacia* Economic Potential**

Acacias produce wattle seed. In its wild form, this seed contains 18% to 24% protein and 50% to 60% carbohydrate. At the macro-nutrient level, wattle seed looks like beans and pulses, a 30 million tonne (and growing) international market. Dry beans sell for approximately \$625/tonne, two to three times the price of wheat.

There is a small wild harvested wattle seed industry. This industry has been valuable in developing niche uses for wattle seed, and in conducting research on human consumption. Current wild production averages 10 tonnes per year.

In addition to its macro-nutrient value, wattle seed may have health and functional food benefits. Besides its low fat, high protein, gluten free, and high dietary fibre virtues, wattle seed is a low glycaemic index (GI) food, and will lower the GI for other foods in which it is mixed. This makes wattle seed a potentially attractive product for dietary management, particularly for diabetics. Furthermore, we need to investigate the potential for wattle seed husk to compete with high value dietary fibre sources such as psyllium seed, and for wattle seed oil to become a high value culinary product.

Wattle seed profitability will be driven by seed yield, seed price, and harvesting cost, and more research and development is required in all these areas. This is typical for prospective new crops. It is highly likely that the industry will be based on *Acacias* planted in rows or grids rather than broadcast planting; we will need orderly patterns to support relatively low cost continuous harvesting.

Acacias must be coppiced (cut down) every five to ten years; at which point they regenerate with renewed seed production. The need to coppice means that a food-oriented *Acacia* industry has a forest products component as well. *Acacias* have been used for bark tannin, firewood, and fibre in

the forest products setting. Africa currently has over 500,000 hectares planted in Australian *Acacia* species, mainly for forest products but also for human food use.

The CRC for Plant Based Management of Salinity is likely to lead any effort investigating *Acacias* as forest product-oriented plants. ANPI's niche is *Acacias* for food.

ANPI intends to create a first generation production system based on selected wild *Acacia* strains. This system will be aimed at currently unprofitable land planted in grains. The first generation system needs to earn a reasonable return on its direct costs. Concurrently, ANPI intends to commence plant breeding and development programs, to produce second generation production systems. These systems will be based on commercial *Acacia* hybrids, which will display improved yields and other economic enhancements.

It is not yet clear if *Acacias* are most economically planted in tight grids as a monoculture, or in looser grids with another plant or plants. There is also the possibility that *Acacias* might work economically in mixed grain/livestock production environments, where after establishment livestock grazes among *Acacia* plantings. Again, these questions require more research.

Acacia Environmental Potential

Acacias possess many attractive environmental features. In particular, as woody perennials they are a better water management plant than annual grains. Because *Acacias* will grow in relatively disturbed and degraded soil, where recharge is likely to be highest, in commercial cultivation *Acacias* may become a particularly effective salinity abatement tool.

More generally, *Acacias* are better for soil quality than the annual grains they replace. Their root systems aerate the soil, they build up soil nitrogen and carbon levels, and they require less mechanical intervention, greatly reducing compaction. *Acacias* are also effective anti-erosion plants; they are already used in this capacity in mine site rehabilitation. Although *Acacias* are relatively small trees in the forest products context, in commercial cultivation they will generate considerable carbon credits. Depending on planting systems, *Acacias* may also prove directly useful for biodiversity, as well as indirectly useful as a salinity abatement tool.

Acacias are widely distributed across Australia, and are at home in the mid-rainfall areas currently in grain production, and most problematic for dryland salinity. Because we are focusing on a low volume high value food product, rather than a high volume and relatively low value forest product, transport economics are less problematic. *Acacias* can potentially bring their environmental benefits to any land currently planted to grain.

ANPI is developing a cultivated *Acacia* industry based on its economic potential. *Acacia*'s environmental benefits, however, are an important underlying driver behind this effort. These environmental benefits are likely to translate into economic returns as well. As salinity and carbon credit markets develop, any payments received by *Acacia* planters will offset establishment costs. *Acacia*'s environmental benefits, particularly recharge control, also lower the economic hurdles to *Acacia* replacing unsustainable grain land in mixed farming situations.

Acacia Social Potential

ANPI is aiming for *Acacia* production systems that convert current unprofitable land into at least marginally profitable use, with a substantial environmental benefit in soil and water quality. Achieving this outcome will automatically produce social benefits, through higher rural profitability and sustainability. There are also potential direct social benefits:

- a) Wattle seed post-harvest processing and value adding may be suitable for distributed rural work, rather than centralised processing;
- b) Wattle is likely to require more labour per hectare than grains, pastures, or forests, leading to greater employment; and

- c) Rural councils may find *Acacias* useful in managing local water balance problems caused by civic water use. In this “civic wattle” context seed production is less the issue than abating salinity damage to infrastructure.

Required Research

To develop its first generation production system, ANPI must secure answers to the following questions:

- g) Food Science. What are wattle seed’s macro and micro nutrient properties, anti-nutritive properties, and potentials for use on a stand alone and ingredient basis? What special properties, if any, do wattle seed kernel, hull, and oil possess? The answers to these questions determine the likely maximum and minimum wattle seed price in commodity production volumes.
- h) Production and Yield. Which species make the best foundation for a commercial *Acacia* industry? How should we efficiently establish these species, and in particular what microbial and other sub-soil preparation is necessary for establishment? What production systems (grid pattern, co-production plants, cultivation techniques) are likely to work best? What yields might we expect in commercial cultivation?
- i) Harvesting Cost. What harvesting and post-harvesting systems are likely to produce the best production cost outcome?
- j) Environmental effects. How can we ensure that *Acacia*’s environmental benefits as a wild plant are maintained in commercial cultivation? How do we value these benefits in economic terms?
- k) Forest products strategy. How can we manage and maximise the economic outcomes from *Acacia* coppicing by-product?
- l) Plant Selection and Improvement Strategy. How do we select our initial cultivars for first generation production? How do we then move to improved commercial hybrids?

ANPI has identified the University of New South Wales Food Science Department to address question (a), CSIRO (Land and Water, Forestry and Forest Products, Plant Industry) for questions (b) and (d), and the University of South Australia’s Agricultural Machinery Research and Design Centre for question (c). Providers for questions (e) and (f) have yet to be selected.

ANPI’s phase one research, to reach a first generation production system, will require approximately three years and a \$3m investment. Within this larger phase there is a “Phase 1a”, currently rolling out, that will require one year and \$1m. This sub-phase will help clarify any major problems or opportunities in food science, environmental sustainability, likely cultivation strategies, and post-harvesting issues. Phase 1a work is based on wild and previous experimental *Acacia* plantings, and wild harvested seed for the food science research.

Paying for Research

The cultivated *Acacia* industry is not yet a commercial investment proposition. There are too many basic scientific questions requiring resolution before private risk capital can be attracted to *Acacias*. On the other hand, as a national interest issue Australia needs to identify and prove up new land use systems, and *Acacias* are a reasonable candidate in this context.

Wattle Alliance Pty Ltd is seeking funding from the following sources:

- a) ANPI proposes to commit \$0.25m to Phase 1 research;
- b) Government R&D agencies, and other Government agencies with interests in new rural industries and environmental sustainability;
- c) Private sector philanthropic organisations; and
- d) Corporations willing to invest on a mixed economic/social development basis.

Early indications are that ANPI may raise reasonable funds through these channels, but it will take two to three years to build up the required funding base.

There is a disconnect in Australian funding between identifying candidate solutions, and rolling out these solutions. The disconnect arises at ANPI's current development point: we have a reasonable candidate, but need to fund non-commercial R&D to better define the eventual production system.

Conclusion

ANPI is confident that food-oriented *Acacia* cultivation is a legitimate candidate, hopefully among many candidates, to replace some existing rural land use with more profitable and sustainable new uses. We are now moving from pre-feasibility to first phase R&D on this candidate.

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Acacia is an extremely diverse plant group in the Australian landscape with 1165 taxa (Flora of Australia Volume 11A and B). There are forest trees reaching over 30 m in height, shrubs and ground covers, and the genus is represented in most major Australian ecological regions (not above the treeline in Snowy Mts, I believe!). Fewer than 100 taxa have been documented as producing edible seeds eaten by Aboriginal people, but the genus is a major food source for native fauna.

Genetic issues include the tremendous genetic variation between and within species. This has implications that are both negative, in terms of the scale of screening work required, and positive, in terms of increasing the chances of selecting useful genotypes. CSIRO Forestry and Forest Products has been involved in collection, characterisation, domestication and breeding of many *Acacia* taxa and we have insights into some of the features of the genus that affect breeding and improvement (species complexes, provenance and sub-specific variation, polyploid series, pollen grains in polyads, and small flower size making controlled pollination very difficult). The genus is generally quite precocious and the generation time from seed to seed can be as short as 12-18 months. We have developed isozyme, RFLP and molecular markers for *Acacia*, and vegetative propagation techniques for several tropical species.

Plant growth and habit, flowering, seed size and seed nutritional factors are all under genetic control to a strong degree. Before proceeding with domestication and breeding, it is important for the prospective industry users to specify “ideotypes” for target species – plants with particular combinations of ideal characteristics (adult size, habit, inflorescence and pod characteristics, seed size and characteristics, etc.), towards which breeders can aim. We have started this process in collaborative work we are doing with village communities and NGOs in the Sahelian region of Africa who are interested in species such as *A. colei*, *A. toruosa* and *A. tumida*.

Based on previous work with these and other species, the improvement process would proceed along the lines of -

1. Systematic sampling from a set of natural provenances to capture the genetic diversity present across the geographic ranges of target species/species complexes.
2. Evaluate species and provenance performance in well-designed field trials to yield information on environmental tolerances, seed yields and seed nutritional factors.
3. Identify best natural provenances and establish further experimental plantings.
4. Make selections (either by collecting seed, or by vegetative propagation) from initial trials and later plantings of best provenances, based on an understanding of population diversity and some readily measured productivity and nutritional parameters.
5. Use the selections to establish breeding populations (for outcrossing species) or, in the case of self-fertilizing or apomictic species, for multiplication gardens where seed of desirable genotypes is multiplied. These stands would form the breeding population for intensive selection and breeding.
6. In some cases it may be possible to develop the first experimental plantings (activities 2 and 3 above) into interim seed production areas.

Selection and breeding would be done in conjunction with work on silviculture, plantation site characterisation, species-site matching, and harvesting. There are issues of weediness and response to predation by native fauna that also need to be addressed.

Opportunities and Constraints for Developing Large Scale Markets for Wattle Seed and its Components with a Specific Focus on Health and Nutrition

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Introduction

Most of the current drive to grow and use wattles seems to be agronomic, for example drought resistance, soil improvement capacity etc. The sole existing nutritional attribute of *Acacia* plants in a western industrial context is the exudative gum (Gum Arabic) from *Acacia senegal*. Scarcity of this gum could assist in developing an Australian industry around wattles however it is unlikely to be enough by itself to sustain a broadscale industry.

Gum arabic was used widely by the food industry. Its value derives from the unique structure of the gum which is a carbohydrate shell around a protein core. This gives it the semi-unique property of thickening without excessive viscosity at low concentrations. Drought and civil unrest (plus some quality issues) in Africa have seen its use curtailed with modified starches replacing it, however they are not as effective and are often viewed as ‘unnatural’. Gums from other wattle species have been examined and it appears they may also have limited application. In addition, apparently regulations limit the term “gum arabic” to that from *Acacia Senegal*. It should be noted that *Acacia Senegal* is not a native Australian species so it may not be desirable for it to be established in a broadscale sense.

The potential useful fractions of the *Acacia* plant for food and medicinal use include:

- Gums and mucilages (seeds, exudates) – food ingredients
- Leaves – forage, tannins
- Seeds – protein, gums for food use

Gums and Mucilages

The greatest potential use of the gums and mucilages is as stabilisers or thickeners, however application depends on physico-chemical properties. Major issues associated with entering such a market are:

- Price – strong competition from current products
- Availability – need a stable supply
- Regulatory issues – if there is no history of traditional use, then there may be toxicological issues.

Dietary complex carbohydrates have established health attributes, for example soluble non-starch polysaccharides (NSP) are recognised agents for lowering plasma cholesterol in humans. However, competition is strong from existing products (guar, psyllium, oats etc) and the structure of *Acacia* gums make their effectiveness doubtful. In the US (but not Australia) substantial health claims are allowed but need documentation.

Leaves

Leaves from specific wattles (eg *Acacia angustifolia*) have strong bactericidal actions in vitro and may be useful in control of infectious disease. However, it is not clear if this action is specific. For example, during an outbreak of cholera in Africa, that part of the population that were regularly consuming the leaves of *Acacia angustifolia* did not become infected. *Acacia* could be useful as biocontrol agents but they are powerfully anti-nutritional in animals at quite modest levels of intake. Safety and substantiation are major issues for human intake.

Seeds

One of the major problems associated with wattle seeds is that they are small. It is possible that seeds may contain specific agents (eg for cholesterol control) but bioprospecting is expensive. Proteins are unlikely to exert a substantial health or food processing benefit as this market is saturated. However the NSP market could be valuable.

Overarching Issues

In conclusion, some of the overarching issues are:

- The cost to benefit ratio for producing a food ingredient like NSP is high, that is a high cost for limited benefit. However if a potential anti-cancer agent were discovered, the costs would be low relative to the eventual benefit.
- Speed to market is a major issue and depends on the need for toxicology or substantiation. Food processors are unlikely to be interested in assisting the development of a food ingredient that will be costly and will take a long time to reach the market.
- If it is considered a novel food or ingredient, then there may be constraints in terms of proving safety or efficacy.
- Supply may be a constraint. For example, will it be possible to produce enough wattle seed or gum to guarantee a reliable supply to the appropriate markets.

Opportunities and Constraints for Developing Large Scale Markets for Wattle Seed and its Components with a Specific Focus on Food Processing

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The table below presents a comparison of wattle seed with chickpeas and lupins. The table shows the substantial differences in both production volumes and price per tonne. The protein, fat and carbohydrate components are comparable to chickpeas, and this paper uses the development of the Australian Chickpea industry as a reference point for any potential wattle seed industry.

	Chickpea	Lupin	Wattle
Australian production (year 2000)	150,000 Tonnes	1,235,000 Tonnes	6 Tonnes
Protein % dry matter	22	34	23
Fat	4	5	6
Carbohydrates	62	39	67
Fibre	8	15	30
\$/tonne	\$250	\$200	\$35,000

The following is a brief summary of the current status of wattle seed knowledge:

- 6 tonnes per annum utilised
- up to 12 tonnes per annum demanded
- comparable nutritionally to pulses
- some anti-nutritional factors reported
- allergenicity and digestibility largely unknown
- existing level of processing R&D is low or negligible
- the current market is speciality and novel in nature, and gains some benefit from its 'green clean' image
- the nearest pulse category is mung beans (17,000 tonnes, ethnic food market)

The potential value-adding of products such as chickpeas and wattle seed range from minimal transformation to maximal transformation. Currently most of the chickpea produced in Australia is at the minimal transformation level of grading, cleaning and bagging. These processes are often performed in local operations. Most of the chickpea production in Australia is exported as bagged bean products although some is processed into extruded and hommus snacks. All of this is low level and low cost processing. Even this low level processing can add significant value. For example Kabuli chickpeas market for \$700/tonne, and canned they are sold at \$2 for a 250g can.

Medium level pulse processing is processing for physical functionality such as starches, proteins, fibre fractions, foaming agents and emulsifiers. There are some pea processing plants in Canada and Europe undertaking this type of processing. An example of the added value is field peas (market value of \$250/tonne) which can be processed into pea fibre which markets for \$5.70/kg and pea isolate which markets for \$6/kg.

Nutritional enhancement is the highest level and highest value processing. Examples of target markets include cosmetics, functional ingredients, nutraceuticals, pharmaceuticals and speciality oils and flavours. Examples of nutraceuticals include:

- isoflavones
- anticancer compounds eg protease inhibitors

- phytosterols: lipid metabolism
- seed coats? waxes?
- low glycaemic index

Barley products are examples of a commodity processed to this level in Australia.

The limitations to wattle seed production in terms of processing and value adding include:

- little R&D performed to date
- no commercial processing sites at present – plant costs are unknown
- previous in-house pulse research would support new market development but the development of milling and processing technologies would be required for higher incorporation into food
- there may be a lack of support from food ingredient companies to take up this work, for example chickpea starch work has not been taken up by commercial companies
- the high fat content of the seed may lead to rancidity and relates to the shelf life of the product
- competition in these areas is high, for example from soy
- you can not currently make any health claims in Australia

Some nutritional advantages wattle may have over other commodities such as chickpeas include:

- high protein digestibility
- mineral content richer in phosphorus and calcium than other pulses
- lowers cholesterol levels
- low glycaemic index
- functional composition (to be determined)
- relatively low in anti-nutritional factors compared with lupins

Drivers for a short-term niche opportunity from wattle seed include:

- an interest in plant derived ingredients
- the excellent nutritional status of wattle
- current GM free status
- is an Australian product
- unsaturated market awaiting development

Food technology issues at this level include flavour, colour, sensory and functionality.

In terms of a longer-term large scale opportunity, there is potential to open up new markets through R&D on:

- wattle seed processing and milling operations, for example bakery utilisation
- fully characterise and optimise component functionality, for example ingredient applications
- nutritional and functional ingredient studies

The limitations to a large scale market include:

- A technological breakthrough is required to support development of new markets for wattle seed ingredients.
- Does wattle seed have a competitive advantage, for example there will be competition from pulses?
- Can wattle seed produce ingredients that meet sufficient functionality needs for many applications?
- Can wattle seed be produced at a cost that allows it to be sold at a price the consumer is willing to pay?
- Will geography be an issue? For example, considerations are shipping costs, handling and storage stability, shelf life.

Opportunities and Constraints for Developing Wattle Seed and its Joint Products as Animal Feeds

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Introduction

Trees and shrubs have long been considered important for the nutrition of grazing animals in Australia, particularly where the quantity and quality of pastures is poor for pronounced periods (Lefroy et al 1992). Foliage, seeds and pods from trees and shrubs have the potential to provide both protein and energy supplements during the annual feed gap in Mediterranean environments or during droughts (McMeniman and Little 1974; Bhattacharya 1989; Reed et al 1990). Several *Acacia* species are recognised by graziers for their drought feeding value (Chippendale and Jephcott 1963; Everist 1969). The economic value of these species to animal production will depend on when the nutrients are available (i.e. does foliage/seed/pod production match feed gap or drought) and the concentrations of essential nutrients and secondary compounds.

Investigations of the potential of trees and shrubs (particularly *Acacias*) as fodder sources for livestock in Australia has been limited to the more widespread and better known semi-arid, fodder species such as *Acacia aneura*. This paper will address the potential usage of seed from Australian *Acacia* species for animal production. A brief discussion will also be presented of the leaf fraction as the potential of Australian *Acacias* for livestock has been covered in detail elsewhere (Dynes and Schlink, in press).

Feeding value of *Acacia*

Feeding value of any forage is a combination of dry matter availability (and accessibility) and the value of the ingested dry matter for use by grazing animals. Variation in voluntary feed intake accounts for 50% of the variation in feeding value of forages (Ulyatt 1973). As a consequence, any characteristics of the feed, which affect intake, and the ease of harvesting are critical to the value of feed for animal production. A number of physical and chemical factors will determine both actual intake and utilisation.

Accessibility

The growth architecture of *Acacia* trees and shrubs and the size and structure of the pods and seeds are all likely to limit performance of grazing ruminants. Animals can increase intake rate to partially compensate for a reduction in bite size associated with browsing (for review see Ungar, 1996) but small bite size cannot usually fully compensate for harvesting difficulties. However, litter fall from *Acacia* species (foliage plus fruit) can be as high as 7 tonne/ha/annum, suggesting the quality of litter should be determined in any selection program. Management by seasonally controlling stocking rates, lopping or cutting and carrying are options to increase fodder accessibility to the animal (Goodchild and McMeniman 1986). In the semi arid zones of northern Kenya fruit and flowers of *Acacia* species contribute up to 40 and 20% respectively of the diets of goats (Schwartz and Said 1981). The value of seeds and pods for ruminant feeding will depend in part on the timing of the seed drop and the competition from other species (e.g. birds).

Chemical composition

In general, fruit (husks (carpels) with seeds) have lower crude protein concentration and higher organic matter digestibility than leaves (Gohl 1981). Internationally or in Australia there are few reports of the nutritional value of *Acacia* fruit/seeds for livestock usage. This is despite *Acacia* fruits being used by animals in the dry season when the pods are ripe. In many areas of the world, fruits are collected and fed to cattle and sheep, or sold in fodder markets. In the semi-arid grazing regions of Australia *A. aneura* pods are much sought-after by sheep, either on the trees or after they have

ripened and fallen (Everist 1969). A number of other Australian *Acacia* species have been identified as being sort-after by livestock (Maslin et al 1998).

Chemical compositions of seeds of some Australian *Acacia* species are presented in Table 1 (from Brand and Maggiore 1991). Energy, protein, fat and mineral concentrations vary significantly between species. The amplitude ((maximum less minimum recorded concentration) multiplied by 100, divided by the average concentration) is also shown where sufficient data is available to provide a preliminary indication of the variation within a species. This amplitude should be treated with caution as the samples were field collected and will reflect environmental variation as well as within species variation. However, this restricted data set does show significant variation within species and between species in important nutritional constituents.

Table 1. Proximal composition (% dry matter) in seeds of lupin and oats and some *Acacia* species; the amplitude of the variation within a species is in brackets (Source: Brand and Maggiore 1991)

<i>Acacia</i>	Energy kj/100g	Protein g/100g	Fat g/100g	Na mg/100 g	K mg/100g	Zn mg/100 g	Cu mg/100g m
<i>aneura</i>	1680 (6)	27 (30)	8 (100)	79 (165)	1004 (157)	3.1	9.2
<i>coriacea</i>	1650 (31)	24 (27)	10 (17)	18 (308)	494 (193)	3.4	0.7
<i>murrayana</i>	1559 (42)	22 (37)	24 (36)	31 (288)	577 (180)	2.3	0.4
<i>victoria</i>	1501 (35)	19 (53)	20 (55)	35 (197)	806 (132)	2.3	1.2
Lupins	1890	34	7	74	790	3.5	2.4
Oats	1940	11	7	44	430	2.6	1.3

Acacia proximal composition compares favourably with that recorded for the traditional supplementary feeding grains of oats and lupins for sheep and cattle.

Grazing sheep have access to seed, or fruit depending on the *Acacia* species and the time of the year. Some *in vitro* and *in vivo* nutritional evaluations of *Acacia* pod and seed have been carried out and provide an indication of the potential nutritional value of *Acacia* fruits for animal production. Ngwa et al (2001) used nylon bags to estimation the digestibility of a range of *Acacia* species pods in comparison with *Leucaena leucocephala* pods (Table 2).

Table 2. Nylon bag dry matter (DMD) and protein digestibility (PD) (in g/100gDM) for the fruit of *Leucaena leucocephala*, and four *Acacia* species.

Component	<i>L. leucocephala</i>	<i>A. erioloba</i>	<i>A. karoo</i>	<i>A. nilotica</i>	<i>A. sieberiana</i>	<i>A. tortilis</i>
DMD	63.9	62.9	65.5	85.5	79.0	81.1
PD	89.2	88.8	86.8	93.6	94.2	93.9

The higher rate of dry matter degradation of the *L. leucocephala* pods relative to the *Acacia* may be the result of a higher husk to seed ratio for the *Acacias*. Higher protein digestibility values for *A. nilotica* and *A. sieberiana* were probably due to higher initial washing losses from nylon bags for these species. *A. nilotica* had a slower degradation rate for protein that is probably associated with the catechin gallates that are known to be toxic to rumen bacteria and host animals. Despite these reservations the authors concluded that 0.5 kg of *Acacia* fruit could provide 38-45g of metabolisable protein per day. Feeding of the fruits is also likely to have the additional benefit of stimulating roughage intake. Lowry et al (1993) found that *A. nilotica* fruit used as a supplement on dry Mitchell grass hay, stimulated the intake of dry hay while the sheep remained in negative nitrogen balance. Improving nutritional status with *Acacia* fruit supplementation has positive effects on both liveweight and wool growth.

The presence of husks is likely to reduce the nutritive value of fruit. Ngwa et al (2001) reported significantly lower protein content in the husks of a number of *Acacia* species and *L. leucocephala* (Table 3). However the crude protein content of the husks would be adequate for ruminant feeding as long as the nitrogen was available, i.e. not bound to lignin.

Table 3. Crude protein content (g/100g DM) of fruit, seeds and husks of *Leucaena leucocephala*, and four *Acacia* species.

Plant part	<i>L. leucocephala</i>	<i>A. erioloba</i>	<i>A. karoo</i>	<i>A. nilotica</i>	<i>A. sieberiana</i>	<i>A. tortilis</i>
Fruit	24.7	12.4	19.3	14.9	17.4	19.1
Seed	30.4	23.3	28.1	19.7	22.3	32.0
Husk	8.4	10.4	11.1	13.2	14.8	13.0

The fruits from *A. tortilis*, *A. albida*, *A. nilotica* and *A. sieberiana* have been evaluated in comparison with more traditional extracted protein meals (Tanner et al 1990). In general *A. tortilis* and *A. albida* appear to have a nutritive value comparable to that of the extracted protein meal when offered as a supplement to maize stover. Lower growth rates and feed intakes occurred with *A. sieberiana* and *A. nilotica*, which the authors attributed to the phenolic compounds and proanthocyanidins in the fruit. The extent of digestion of the seed in the fruits ranged from 54% for *A. tortilis* to 96% for *A. sieberiana*. Low apparent digestion of *A. tortilis* seeds would mean a significant loss of potentially available nitrogen and energy to the animal but effective spreading of seeds if that is a desirable outcome. Ingestion and passage of seed through the digestive tract and subsequent appearance in the faeces permits seed distribution and improved seed germination (Gwynne 1969).

Cleaned seed has been proposed for human consumption and extensive studies of the composition of a number of *Acacia* species has been undertaken (Brand and Maggiore 1991; Rivett et al 1983). A number of species have been identified for potential commercial production for human consumption (Simpson and Chudleigh 2001). Although the emphasis in these studies has been on the potential for human consumption, the possibility of livestock utilisation should not be overlooked. Simpson and Chudleigh (2001) have identified that harvesting technology may pose an economic constraint on the human-food industry potential, particularly in the early phase of establishing the industry. Livestock can self-harvest seed that may be uneconomic to harvest in the early stages of plantation and harvesting technology development, thus providing an alternative economic return beyond that obtained from inefficiently harvested product alone.

Secondary Compounds

Plants that grow in harsh environments frequently contain secondary compounds, which play a role in plant survival. Secondary compounds may function to enable the plant to tolerate the soil, water and climatic stress or may act as deterrents to grazing. *Acacias* are reported as having a wide range of secondary compounds potentially toxic to herbivores (eg tannin, oxalate, nitrates, cyanides, selenium, fluoroacetate, alkaloids) and these are summarised elsewhere (Dynes and Schlink, in press), however there is little data on the levels of these compounds in seeds and pods.

These compounds should be identified early in the evaluation of plants for animal production and species or provenances with low levels should only be considered in further evaluation of nutritional potential in extensive plantations. Where these compounds exist in plants within current grazing systems then animal management strategies must be put into place to minimise the impact of secondary compounds on animal production if the proposed strategies are economically viable.

Non-seed Products

Leaf is the major non-seed product though consumption of twigs and flowers has been reported. Historically, in Australia *Acacias* have been browsed *in situ*, as part of the landscape. This usage has usually been as survival feed as the native pastures disappear in drought conditions. The effectiveness of the protein can be severely restricted by the presence of secondary compounds in the leaves. Dry matter digestibility and crude protein levels can vary widely between species and probably within species (Table 4).

Table 4. Proximal composition (g/100g dry matter of leaves) of some commonly grazed *Acacia* species (Source: Dynes and Schlink in press).

Species	Crude Protein	Ether Extract	Crude Fibre	Ash	OMD <i>in vivo</i>	OMD <i>in vitro</i>	DMD <i>in vitro</i>
<i>A. aneura</i>	9-20	2-6	24-37	3-7	35-63	35-50	
<i>A. cambagei</i>	11-13	3-6	14-16	11-14		44	
<i>A. pendula</i>	13-16		26-30	6-9	43	43-50	
<i>A. farnesiana</i>	15-24	2-6	10-22	4-8		54-68	
<i>A. albida</i>	17-20	2-3	12-22	6-9	53		
<i>A. seyal</i>	11-29	1-7	8-23	1-8			
<i>A. ampliceps</i>	1-2			1-25			50-55
<i>A. brumalis</i>	1-2			1			36-48
<i>A. cyclops</i>	1			1			39-44
<i>A. ligustrina</i>	9-12			1			44-52
<i>A. saligna</i>	5-15			8-14	31-60		

Ruminant livestock require approximately 55g/100g dry matter digestibility and 8g/100g dry matter of crude protein for maintenance requirement (Standing Committee on Agriculture 1990). The data in Table 4 shows that some species meet this requirement, however, there is considerable variation within the species. This variation within species has been highlighted by the studies of the Oxford *Gliricidia* collection that showed large variation in both leaf *in vitro* dry matter digestibility and nitrogen content within the twenty-six lines grown in the same environment (Schlink et al 1991). Nitrogen content ranged from 3.00 to 4.15%, dry matter digestibility from 67 to 80% and dry matter yield from 2.1 to 6.5 tonnes/ha with not relationship between dry matter yield and nutritional parameters. This poor correlation between plant yield and nutritional quality indicates that nutritional quality as well as yield should be taken into account in the selection of species for animal usage. These sorts of systematic studies need to be undertaken for *Acacia* species and accessions before they are considered for large scale planting. The reported information for *A. aneura* and *A. saligna* suggest that within these species there could be considerable variation in nutritional value that can be exploited in selecting suitable genotypes.

Secondary compounds in *Acacia* leaves have inhibited animal production from a number of species. These secondary compounds are predominantly tannins, and extensive studies have been undertaken to limit their impact on animal production. Low levels of tannins can be beneficial to animal production through bloat protection and protecting protein from rumen degradation. Polyethylene glycol has been successfully used to reduce the impact of tannins in both *A. saligna* (Ben Salem et al 2000) and *A. aneura* (Pritchard et al 1992). A number of supplements for grazing animals have also been proposed but these are an added cost to the grazing system that should be addressed in the first place by selecting species or accessions with low secondary compound concentrations. Alternatively, developing a grazing system where animals can select a diet that minimises the intake of deleterious secondary compounds may be used.

The harvesting of seed and forage from wattles for feeding as a supplement or for intensive animal production could also be considered, though viability of this option would depend on the yields per hectare (both in tonnage and energy density), ease and cost of harvest. This would probably only be an economic option where the supplement was a by-product of harvesting for another purpose.

Predicting animal performance

Once plant quality characteristics of selected *Acacia* species have been estimated, the nutritional management program for ruminants, GrazFeed (Freer et al 1997) may be used to estimate potential animal performance. For example, weaner wethers grazing *Acacia* foliage and pods with an estimated digestibility of 47% and protein content of 9% are predicted to lose 80g of live weight per day. Weaners offered this combination with dead pasture (51% digestibility) were estimated to have a modest weight gain (13g/day), due to increased capacity to select higher quality components in the diet. However if *Acacia* species/composition resulted in a digestibility of 55% and protein content of

11% then weaners could maintain live weight with an intake of 900g per day of *Acacias* alone. These predictions would require validation by animal feeding before recommendations could be made since no account of secondary compounds or limitations to forage acquisition are included in these estimates.

Conclusions

Animal utilisation of *Acacias* in farming systems could be improved through selection of *Acacia* species, which will establish and provide feed for livestock during feed gaps and droughts, providing issues of fodder accessibility and secondary compounds are overcome. Successful selection will require simultaneous determination of yield, nutritional and anti-nutritional factors for ruminants followed by animal studies. To-date the potential of *Acacia* species for animal production has not been studied in any systematic fashion to determine the potential of any of these species for animal production in Australia. This situation exists despite the extensive use of the species in periods of nutritional stress and increased plantings of *Acacia* species of unknown nutritional value for potential livestock production.

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Water Use and Sustainability of *Acacia* Crops in Southern Australian Agricultural Systems

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1. Introduction

Acacia is a large and diverse genus with a wide range of plant form and function. It provides a large base from which to select germplasm with potential for commercial development. Selection of germplasm can be approached from two directions:

- selection based on biological characteristics that are desirable for a crop plant.
- selection based on the potential for production of commercially attractive materials.

These two categories of selection criteria are interrelated, i.e. the biological potential may help determine what the best product might be, or alternatively, the desired product will influence the selection of biological attributes.

By far the dominant objective in the development of new crops is scale. If we are to entertain remedy of the serious problems of salinity and sustainability in southern Australian agricultural systems, then we must be thinking of new 'sustainable' crops that could be planted on a very large scale. These crops will need to have a presence, at least intermittently, on virtually every hectare of agricultural land. Hence this overview will focus on *Acacia* as a source of germplasm that might have very large-scale application. It will approach this from the direction of the biological attributes of *Acacia* that will be desirable for large-scale crop plants.

The genus *Acacia* will not be the only candidate to be scrutinised for sustainable crop development prospects. The task of developing perennial crops to help make Australian agriculture sustainable will take a couple of generations and many millions of dollars of R&D investment. However, this investment should, at every stage and for every option, be based on rigorous assessment of likely comparative return on investment in the long term.

Hence the question addressed in this overview is – what biological attributes of *Acacia* make it attractive for crop development and what are the most prospective directions for investment in *Acacia* R&D?

2. Crop types and crop rotation

To be able to assess the potential for *Acacia* as a large-scale crop its role in the system of agriculture needs to be considered. Three conceptual woody perennial crop types have potential for development for wheatbelt agriculture:

1. Short rotation coppice crops: where harvest occurs every 2 to 5 years from successive crops regenerated from rootstocks that re-sprout or coppice after each harvest. Interest in short rotation coppice crops has been stimulated by the experience with mallee development in W.A. (Bartle 2001). Coppice crops are costly to establish (using nursery produced seedlings) but are ready for harvest at an early age, and can regrow many times from the cut stump. They are well suited to planting in permanent belts oriented along the contour, or in other strategic alignments, to intercept downslope water movement. As discrete linear belts they are readily integrated into large-scale annual cropping systems in what has become known as alley farming.
2. Short rotation phase crops: where the crop occupies a phase within the annual crop rotation and is harvested once and removed at age 3 to 6 years. The high cost of seedling propagation is a significant barrier to profitable production of large-volume, low-value products by phase crops (Harper *et al.* 2000). Hence species that can be readily established by direct seeding,

such as those with large seeds, are the most likely candidates to be developed. Phase cropping can be used to dewater cropland where soil characteristics limit the rate of lateral movement of subsurface water and therefore limit the potential for water consumption by permanent belts of perennial plants. Phase cropping has yet to attract much investment in research and development, despite being conceptually attractive.

3. Long rotation crops: where the production cycle is greater than 10 years but may be as long as 100 years. Long rotation crops require intensive, long-term capital investment, and careful site selection. They are suited to planting in belts or small blocks, and may produce timber and non-wood products as well as provide shelter and aesthetic benefits.

Within the diversity found in the *Acacia* genus there are many species that could be developed for any of these crop types. Some species have good tree form, good wood quality or potential for seed and gum production that might be suitable for long-rotation cropping. Other forms have the ability to coppice or sprout from the stump after harvest and could be used as short rotation coppice crops. Some species establish readily from direct seeding and might be suitable for use as a short phase in annual crop rotations. Both coppice and phase crops could produce low cost biomass for industrial products.

3. Economic comparison of crop types

The three conceptual woody perennial crop types fill quite different roles in agricultural systems. Bartle *et al.* (in press) present an economic comparison of these roles. In this analysis they compared discounted cash flows for each crop type, and for conventional agriculture based on annual-plants, over a 25-year period for the 400 mm rainfall zone in the WA wheatbelt.

Production cost and yield were estimated for each crop type, and then used to calculate the 'stumpage' (selling price of the crop standing in the field) that would be necessary for each crop type to achieve an equivalent return to conventional agriculture (i.e. averaging \$65/ha annually over a 25-year period). These calculated 'break even' stumpages were then compared with estimates of stumpages that are likely to be paid by timber and biomass industries. The analysis also contrasts two establishment techniques, conventional seedling establishment and direct seeding. Note that no allowance is made in this analysis for any positive or negative indirect effects of woody perennial crops such as erosion control, shelter, salinity control, and interaction with other crops. The results are summarised in Table 1.

Table 1: Impact of establishment technique on the economics of woody crop types in the 400 mm annual rainfall zone (from Bartle et al. in press).

Crop type	Seedling establishment			Direct seeding			Estimated stumpage ⁴
	Break even ¹	Average Debt ²	Calculated stumpage ³	Break even ¹	Average Debt ²	Calculated stumpage ³	
Coppice	14	931	14	8	332	8	15
Phase	16	432	32	8	126	14	15
Long rotation	25	1417	130	25	696	87	60

¹ years to break even.

² average debt (\$ per hectare) over period to break even.

³ selling price necessary to make return equivalent to that of conventional agriculture (in \$ per tonne of biomass for short rotation crops, and \$ per cubic metre of wood for long rotation crops).

⁴ estimate of stumpage likely to be paid for each crop type (same price basis as ³).

In their integrated mallee processing feasibility study Enecon (2001) showed a stumpage price of \$15 per tonne to be a commercially viable purchase price for mallee biomass feedstocks. This has been used here as an indication of a likely competitive price for biomass feedstocks for industrial products.

Table 1 shows that coppice crops established by planting seedlings can produce biomass for a stumpage of \$14 per tonne. If these crops could be established by direct-seeding, biomass could be produced for as little as \$8 per tonne, a price likely to stimulate large-scale demand by wood processing and bioenergy industries. In contrast, phase crops established by seedlings would produce biomass at \$32 per tonne, over twice the likely price. Direct-seeding is essential for phase crops if they are to be produced at \$15 per tonne.

The economics of long rotation crops appear less favourable. Even using direct-seeding, the selling price would have to be above the estimated stumpage of \$60 per cubic metre for timber at final harvest (or its equivalent in other products).

For long-rotation timber crops the average debt load of \$1417 per hectare over the 25-year period to harvest indicates a major financing constraint that is likely to be beyond the resources of most farm businesses. For this reason, long-rotation timber crops are unlikely to be planted on a large scale, unless long-term arrangements involving external finance are developed. The debt level is much lower for coppice and phase crops, and also needs to be carried for a shorter period, because the time to break even for these crops is shorter than for long-rotation crops. Coppice and phase crops are more likely to be within the financing ability of farm businesses.

This financial analysis indicates several important directions for the development of *Acacia* crops:

- Direct seeding is a major cost saving. Hence large-seeded plants like *Acacia*, that are relatively easy to establish by direct seeding, have a significant economic advantage over small seeded ones like eucalypts, for which there is currently no adequate direct-seeding method.
- Direct-seeded *Acacia* phase crops could produce biomass at a similar cost to mallee coppice crops. The cost of re-establishing phase crops after each harvest is minimised by direct seeding.
- Some *Acacia* species might combine the advantage of direct seeding with the ability to be managed as coppice crops. They could produce very low cost biomass.
- Long-rotation *Acacia* species that might produce only a final harvest crop (timber) carry the burden of large, long-term capital requirement and are not likely to be attractive for development as large-scale crops.

This analysis suggests the best potential for large-scale production from *Acacia* lies in development of phase crops. A second option is that if there is strong enough coppicing ability in *Acacia* it could open the possibility for coppice crops with low cost of establishment.

4. Hydrological setting for woody crop types

Since the major motivation for large-scale use of new *Acacia* crops is to improve salinity control, it is important to define the hydrological setting in which they will be expected to perform. In terms of hydrology Bartle et al (in press) use two major categories of planting sites:

Recharge sites: where the water table is well below the soil surface and rainfall may infiltrate to some depth in the soil profile. Sub-categories are:

high recharge sites: where light-textured soils permit rapid, deep infiltration of rainfall; water use and productivity under annual plant agriculture is comparatively low because some water escapes below the annual plant root zone; potential for lateral movement of water at depth within the profile is high; and groundwater salinity is comparatively low. On these sites, permanent woody crops in belt configuration can develop deep root systems with the potential to intercept down-slope movement of perched or deep groundwater, as observed by White *et al.* (2002). This mode of action is a form of recharge prevention, applied indirectly by extraction of groundwater near the point of recharge. This is characterised by Bartle (1999) as ‘water coming to the trees’.

low recharge sites: where soils are heavier-textured; leakage past annual plant root systems is less; salt storage in the profile is greater; groundwater salinity is higher; and lateral transmission of groundwater is slower. On these sites phase crops could be used intermittently but

extensively, to reduce soil water storage and net recharge (Harper *et al.* 2000). This mode of action relies totally on direct recharge prevention, and is described by Bartle (1999) as ‘taking the trees to the water’.

Discharge sites: where infiltration is impeded by a shallow water table. Groundwater is usually brackish or saline and may be discharging from the surface. The soil is poorly drained and only species that can tolerate waterlogging and salinity are present. Barrett-Lennard (2000) has proposed three subcategories based on potential productivity:

high: where groundwater is sufficiently deep that salt accumulation in the upper soil profile is not great enough to affect productivity.

medium: where the soil is salt affected but still able to support salt tolerant species.

low: where salt has accumulated to the extent that only halophytes can survive.

There are many *Acacia* species that could be developed for each of these site types, except perhaps for the low productivity discharge sites. Large-scale development of *Acacia* crops is likely to focus on species suited to recharge sites and high productivity discharge sites, because plant survival and growth rates are likely to be highest in these areas.

5. Matching *Acacia* crop and site types

Section 3 indicated that large-scale *Acacia* crops are most likely to be developed as phase crops, although there may also be some potential for coppicing species. Section 4 indicates that the most relevant site type for *Acacia* phase crops is likely to be ‘low’ recharge areas, although they could also be used periodically to enhance recharge control between belts of coppice crops on ‘high’ recharge areas.

We can therefore sketch out the likely *Acacia* phase crop ‘ideotype’ and management practice. *Acacia* crops will be large seeded and readily established, probably using conventional large-scale cereal seeding equipment - regular replanting of phase crops demands a low cost operation to make them commercially viable. *Acacia* will establish rapidly and grow vigorously, expressing its ‘pioneer’ capability. The extensive intermittent presence of phase crops would also be an effective way to use the nitrogen fixing potential of *Acacia*. Nitrogen input during the *Acacia* phase could make a significant contribution to nutrition during the annual crop phase (Mele and Yunusa, 2001). A woody crop phase also has potential to improve soil structure (Yunusa *et al.* 2001), but presents some new challenges to develop efficient methods of cleaning up trash and stumps after harvest.

The major objective in any development of radical new large scale *Acacia* crops will be to make some progress in water use and salinity control.

6. Water use potential of *Acacia* crops

6.1 *Acacia* as a phase crop

For *Acacia* crops to be compatible in rotation with conventional annual crops they will need to be effective in providing the ‘break’ or ‘resting phase’ necessary to arrest the build up of annual crop pests and pathogens. This has historically been done with an annual pasture phase. Most commonly the annual pasture had a strong legume component (clover ley system) and so the break has also been an opportunity to maintain soil organic matter, soil structure and nitrogen content. Grazing and other aspects of pasture management also provided the opportunity to discriminate against crop weed species. In recent years this has become an especially important purpose of the break, to counter the emergence of herbicide resistant weeds.

The optimal duration of an *Acacia* phase will be a compromise between several factors - number of years before a break is needed, time to produce a reasonable *Acacia* crop yield, required depth of dewatering of the soil profile, and the proportion of the rotation period needed under the conventional (and probably more profitable) annual crops to maximise profitability. Given the interplay of these factors it is likely that the *Acacia* phase will be limited to 3 to 4 years in a rotation period of 10 years.

From a simple water balance perspective, a 3 or 4 year *Acacia* phase crop will need to use the surplus water from 6 or 7 years of annual crops. If the annual phase uses 85% of incoming rainfall and the remaining 15% infiltrates below the root zone, the following *Acacia* crop will have to use water at a rate between 122 and 135% of annual rainfall to reclaim it. A low recharge soil type of medium texture could hold 160 mm/m between field capacity and wilting point (Storrier and McGarity, 1994). In a 400 mm rainfall zone, 7 years of leakage at 15% of rainfall would generate 420 mm of available water, requiring a storage depth of 2.6 m of subsoil (i.e. below the 1 m deep annual crop root zone) or a total soil depth of 3.6 m. Hence the *Acacia* phase crop would have to occupy and dewater a soil depth of 3.6 m within 3 or 4 years. In terms of depth of root penetration and water use this is likely to be easily achieved. Knight *et al.* (2002) observed this level of performance for a silty clay loam at Bridgewater (Victoria) in a 420 mm rainfall area, although it was for a mixed *Eucalyptus* and *Acacia* stand. This stand extracted 399 mm of stored soil water over 4 years from a depth of 5 m. The analysis by Harper *et al.* (2001) also shows that these depths and amounts of water use should be readily achieved.

Hence rooting depth is unlikely to be the limiting factor in *Acacia* phase crops on medium and heavy soils. Other useful selection criteria to seek out species with superior attributes include productivity, rapidity of root penetration, and tolerance of adverse soil physical properties (obstructions to root penetration, waterlogging) and chemical properties (pH, salinity). Although it seems likely that the dewatering task could often be done in 3 years, an extra year or two may be needed to produce sufficient biomass of the right quality (wood size and fibre characteristics) to make the phase crop profitable.

One of the negative outcomes of phase crops is the risk that the dewatered profile will suffer reduced annual crop yield for a period following the phase crop. This effect was observed by Mele and Yunusa (2001), and may occur where stored soil water complements rainfall in generating annual crop growth. On the other hand a dewatered soil profile could be more productive in some circumstances - if it reduces waterlogging in wet areas, or in wet years following the phase crop.

6.2 *Acacia* as a coppice or long rotation crop

If *Acacia* is to be used as a coppice or long rotation crop then it will be desirable for it to have the capacity to extract deep groundwater through deep root penetration. Hence for these crop types deep root penetration will be a major selection criterion. Given that coppice crops may be preferentially used for light soils that permit water to infiltrate deeply it is also likely that such soils will be relatively favourable for deep root penetration.

There are few data on depth of root penetration in *Acacia*. Knight *et al.* (2002) provide three examples from the south east of Australia but their *Acacia* was in mixed plantings with *Eucalyptus* and *Atriplex*. These plantings exceeded 6 m deep root penetration in 4 years. At one site with a sandy soil belts of *Acacia saligna* and *Atriplex nummularia* had roots at a depth of 16 m. In Africa, roots of *Acacia senegal* have been reported at a depth of 32 metres (Deans 1984, cited in van Noordwijk *et al.* 1996).

In belts the lateral root characteristics of coppice and long rotation crops may turn out to be as important as depth. A zone of competition develops along the interface between the perennial and annual crop components. Assessing the costs and benefits of belts of coppicing perennials to incorporate the issues of competition is complex (Stirzaker *et al.* 2002). However, an inherently deep descending root architecture would be highly desirable in diminishing competition while retaining the potential for high water use from depth. Such a root architecture was indicated for tagasaste by Lefroy *et al.* (2001).

7. Conclusions

While virtually any woody perennial is likely to consume more water than annual crops, there is likely to be considerable variability in water use potential between species, especially within such a large and diverse genus as *Acacia*. High water use is an important selection criterion for potential *Acacia* crops that are intended to play a role in salinity control. Partial selection for high water use is

likely to occur coincidentally during preliminary selection of *Acacia* species for commercial crops, since two key factors for commercial success, namely high survival rates in medium to low rainfall areas, and high biomass production rates, are most likely to coincide in plants that are effective at extracting water.

Once several productive *Acacia* species have been identified for potential crop development, further testing will be needed to find particular forms with optimum root architecture and water use characteristics for the crop and site types that are required.

Selection for phase crops will focus on rapidity of root occupation to relatively shallow depth and tolerance of difficult physical and chemical properties of soil profile. In contrast coppice or long rotation crops will require a deep root penetration capability. In addition to these major selection criteria for root systems in relation to water use, there are many other biological attributes and management options that will need to be elucidated to realise the full potential of the genus *Acacia*.

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Options for Harvesting Wattle Seed

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Summary

This presentation broadly describes some options for harvesting wattle seed on a large-scale, low cost basis. It further explores how these and other options might be systematically analysed, as the knowledge base expands.

It points to the need to include other operational aspects, (site preparation, seeding/planting, tending, etc) as their costs represent a high proportion of total costs of producing a short rotation crop. Immediate work is required on species selection and establishing a likely cropping pattern for deep rooted perennial crops, to ensure resistance to drought, a desirable rotation age and maximum seed yields.

Further analysis should precede component and machine development to ensure that resources are directed towards the most likely solutions.

Harvesting Options

Simpson and Chudleigh (2001) refer to four general concepts. These included: the traditional manual method used for harvesting seed for speciality foods, individual tree shakers as currently used for olives and some nut crops, and continuously moving strippers and biomass harvesters that would move along a row or rows of plants.

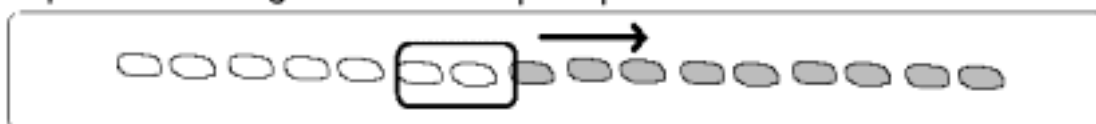
In this presentation the traditional or mechanised methods of harvesting individual trees are not included as they are inappropriate to the large scale, low cost harvesting of such a crop. A continuous moving machine is considered necessary for the efficient harvesting of small trees (Kerruish 1976) and the likely costs of harvesting wattle suggested by Simpson and Chudleigh tends to confirm this decision.

The options considered fall into two categories, those that harvest seed only and those that harvest some or all of the above ground biomass (AGB) to recover the seed, with the remaining components being harvested for some other product or returned to the site.

Harvesting Seed Only

The following options involve a machine moving continuously along a row of wattle trees that may have been shaped by prior operations, harvesting the seed by a number of different mechanisms designed to dislodge the seeds or seedpods and carry them in an airstream to a bin on the harvester. No further consideration is given as to the merits of alternative mechanisms as more needs to be known about cropping patterns, seed distribution and ripening before this is attempted.

Option 1. Beating and air-stream pick-up



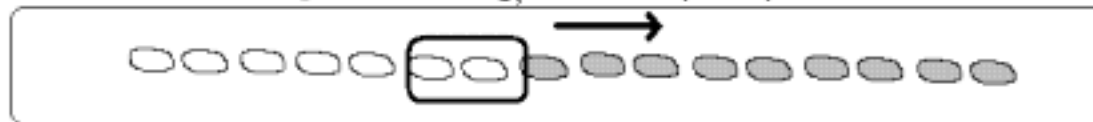
Seed bearing plant would be beaten with a mechanism simulating the manual process as the machine moves continuously along a row.

Option 2. Shaking and air-stream pick-up



This option involves shaking the tree either by the stem or the larger branches of the crown as it moves continuously along a row.

Option 3. Combing + or - shaking, air-stream pick-up



A combing or stripping mechanism, possibly augmented by shaking, would dislodge seed as the machine moves continuously forward.

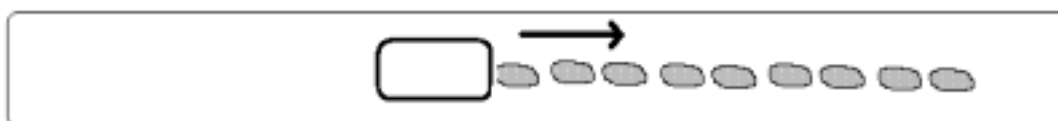
The advantages and disadvantages of harvesting seed (annually?) from standing trees or shrubs are:

Advantages	Disadvantages
• Low machine mass • Low energy requirements • Low maintenance costs • Low operating costs • Reduced operational impact • Minimum biomass removal • Growth directed to seed production • Longer rotations encouraged	• Unknowns associated with cropping patterns, seed presentation & ripening • Unknown impact on plant eg disease consequence of damage • Unknown performance of different mechanical components in harvesting wattle seed • Fibre/biomass not harvested

Harvesting Above Ground Biomass (AGB)

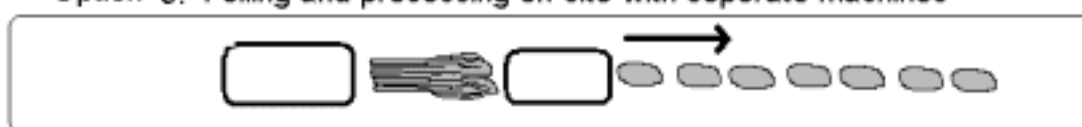
Where markets exist for some or all of the above ground biomass a single operation might harvest the seed and some or all of the woody components, bark and foliage, segregating them if required. The bark and foliage that contain a high proportion of plant nutrients, may be returned to the site. It might harvest the plant only at the end of a rotation and not recover seed.

Option 4. Felling and processing with a single machine



With this option a harvester would recover seed and above-ground plant components. The WA mallee harvester (Giles, 2001) or a Claas biomass harvester might fill this role. The seed might be separated on the harvester or at some point downstream.

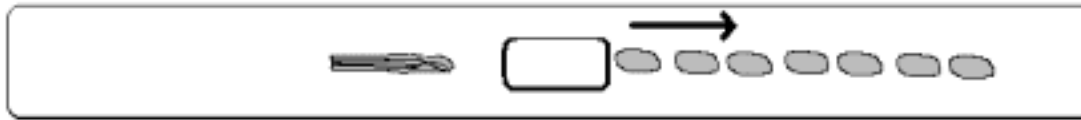
Option 5. Felling and processing on-site with separate machines



Same outcomes as option 4 except that two simpler machines are involved. The first cuts, extracts seed and accumulates stems. The second machine fragments and segregates different components.

Both options 5 & 6 are relevant to final cut for wood / fibre products and a desirable first step in developing option 4 as less complex machines are required.

Option 6. Felling, seed extraction, accumulation and compaction of residues



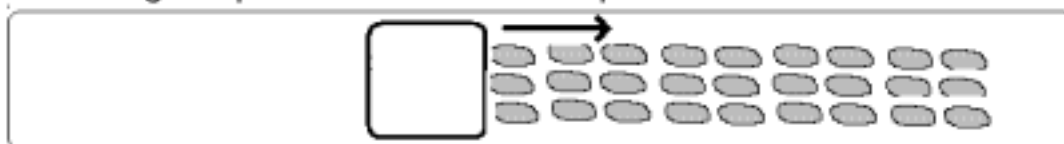
Option six incorporates some ideas being used in harvesting forest residues that are accumulated and compacted into 'logs' to facilitate subsequent handling with processing at the mill. (Brunberg et al. 1998)

Advantages	Disadvantages
- Seed plus all or part of the above ground biomass can be harvested in a single operation. - Recovery of other plant components for fibre or food could reduce seed harvesting costs	- Unknowns associated with yields and coppicing capacity of wattle on very short rotations - Unknown effectiveness of different components in harvesting and segregating different plant components - Heavier machines, higher energy inputs, maintenance, capital and operating cost. - More biomass removed; may be detrimental to sustainability - Much of site potential is channelled into plant growth, not seed production

The above suggests a somewhat more sophisticated machine and a longer, more costly development process, unless a developed or machine is available that could be readily adapted.

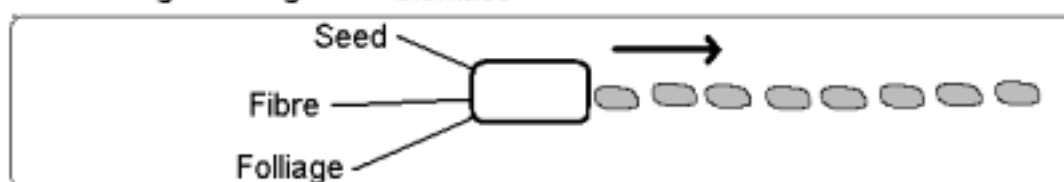
Some Variations of the Above Options

Harvesting multiple rows or broadcast strips



Further work is required to establish the cropping pattern most appropriate to this new crop. Rows or strips may be shaped to facilitate harvesting.

Harvesting above ground biomass



Where the above ground biomass (or part there-of) is harvested, a number of possibilities exist to segregate different components. As well as the seed for example, the woody fibre could be separated from the foliage with the fibre being used for some board product and the foliage for stock food or returned to the site. The technical implications of achieving such a degree of segregation will be depend on the level of contamination accepted in the fibre.

Analyses of Options

It is common to under-estimate the time and costs involved in developing an operational system and the tools required for changed management practice. In forestry this has ranged from 5 to 15 years and several million dollars between the initial concept and a fully developed machine being available off the shop floor. While somewhat lower inputs could be anticipated for a wattle seed harvester, the time and resources could be reduced by the exchange of ideas between the bio-technologists developing the crop and operational technologists concerned with developing operational strategies and tools.

An effective way of achieving this exchange of ideas is by the systematic analysis of chosen options, drawing on the best available biological, engineering and economic knowledge. The cost benefit analysis of options for harvesting wattle seed (Simpson and Chudleigh, 2001) and Rawlins et al (1985) who explored harvesting options for young, regrowth eucalypts, are examples of preliminary analysis involved in developing operational systems.

Further analysis should follow the establishment of **cropping patterns** likely to be adopted. While some form of continuous harvesting is essential, a different crop pattern may be required to that used in annual crops. It is likely that maximum seed yield, longer rotations and some resistance to droughts will be obtained by wider spacing (as in cotton or tea production) of these deep-rooted, perennial plants.

Examples of the systematic analysis of operational options include those by Backstrom and Wahlquist (1972) in their analysis of planting options, Jonsson's (1998) comparison of harvesting systems for stump and rootwood and Brunberg et al (1998) report on options for harvesting biomass fuel.

It is important that the operational focus is not only on harvesting. Olsen (2001) indicates that it costs \$110 to grow a hectare of wheat and \$30 to harvest it; the shorter the rotation the more important it is to consider other operational aspects. Littrell (2001) suggests that both seeding and planting and a wide range of plant arrangements and spacings should be considered. Golob's analysis of short rotation crops (1986) is a good example of an approach that considers establishment, plant production and planting plus spacing and harvesting options.

Such analysis can assist in ensuring that the substantial resources required are directed towards the best options – **not the most vocal proponent!**

For a project of this scale we cannot afford to address species selection and crop improvement only, ignoring the development of an appropriate operational technology.

Forestry experience suggests that little innovation has come from the major international equipment manufacturers; the main contributors have been logging companies, small engineering firms serving the industry and the forest owners. The most successful role of R&D organisations has been to screen and analyse such innovations rather than to introduce new concepts themselves. The two-way dissemination of ideas between researchers and industry is an important component of effective development.

Recommendations

Important gains may be made in plant breeding and cropping trials but the best outcome will be achieved by pursuing this goal in partnership with the ongoing analysis of operational alternatives. Further work should involve:

- The selection of species most suitable for seed production and the establishment of trials to establish likely cropping patterns.
- The continuing analysis of different technical solutions and management strategies, drawing on the best available biological, operational and economic information.

Examples of such analysis are provided to suggest how this might be done.

The developing and testing of critical components, such as mechanisms for dislodging and recovering seed from growing plants, should proceed after further work on crop development and the identification of the more promising cropping patterns have been explored.

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An Analysis of Possible Harvesting Systems for *Acacia*-Based Agroforestry

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(Prepared for consideration at the Wattle Seed Workshop, Canberra, 12 March 2002)

1 Introduction

The report by Simpson and Chudleigh (2001), in response to its Terms of Reference, concluded that the key drivers of the economic viability of wattle seed production were the harvesting method and cost, the yield and the farm gate price. The report also included an Appendix that ranked 11 potential agroforestry enterprises based on *Acacia* harvested as biomass.

Wattle seed harvesting and *Acacia* biomass harvesting are two entirely different operations. The aim of a wattle seed harvesting operation is to maximise harvesting rate in ha/hr. It can take advantage of existing grain transport and operating infrastructure, which are well established and have predictable costs.

Biomass harvesting is governed by the need to harvest and handle material at high mass flow rates and in large quantities. It can only be cost effective when the accompanying transport and processing arrangements have been developed, are operating, and have been optimized.

The following paper analyses both of these operations within the context of conventional grain harvesting and cane harvesting operations.

2 Wattle Seed Harvesting

In order to get some sort of perspective on what a wattle seed harvester may look like, we can use a grain harvesting operation to establish some sort of scale.

A grain harvesting operation could be in an 8T/ha crop, and have a harvester capable of an effective rate of 16T/hr after delays, at a contract rate of \$240/hr. The harvesting cost/tonne is therefore \$15/tonne, and cost/ha is \$120/ha.

On-farm transport using chasers to a farm bin could be \$4/tonne, and off-farm transport to a silo 100 km distant could be \$20/tonne.

The total harvesting and transport cost/tonne is therefore \$39/tonne, and the farmer grows a crop and survives on the difference between \$39/tonne and a selling price of \$150-\$200/tonne, roughly a \$140 margin.

Broadacre non-irrigated *Acacia* could produce say 1t/ha of seeds, which in grain crop terms is a pretty poor crop. An imaginary wattle seed harvester with the same width of front and ground speed as this grain harvester would take the same time to cover a hectare and collect just a tonne of seed, and the harvesting cost/tonne would be \$120. Transport costs would be the same for that tonne of seed, so the total cost of harvesting and transporting that tonne of seed would be \$159.

Grain harvesters that work at this sort of rate are the result of over 100 years of research and innovation, and they work in crops that have been selected and bred to make machine harvesting as

easy as possible. It is difficult to assume that a wattle seed harvester could achieve anything approaching the sort of overall efficiency routinely achieved by grain harvesters.

A more realistic assumption for a wattle seed harvester would be for a machine 4m wide, with a ground speed of 2.5 kph and a field efficiency (or machine availability) of 0.5. This machine would take 2 hours to cover a hectare, and the harvesting cost/tonne would be \$480/tonne at the same contract rate.

Transport costs would be the same, giving a harvesting and transport cost of \$529/tonne.

This figure is sufficiently close to the value of \$750T/ha used in the modeling in the report (Simpson and Chudleigh 2001), which can be restated as \$600/tonne using the assumed yield of 1.25T/ha. This gives some confidence in the proposition that a wattle seed harvester should have specifications of the order assumed.

If the harvesting cost could be reduced to the “best case” \$375/ha, or \$300/tonne, then the harvester would have to be capable of harvesting that tonne for \$(300-39) or \$261, taking 1.09 hours to do so. To create a harvester that can harvest 1ha/hr is a reasonable research and development target.

Given that the break-even farm gate price in all the scenarios presented in the report is approximately 25% greater than the harvesting cost, a break-even farm gate price with such a harvester would be about \$0.37/kg. With a farmers’ margin of the order of \$0.14/kg, \$0.51/kg or \$510/tonne is the sustainable farm gate price.

There is technical risk in developing a harvester to meet this specification, and there is a marketing risk in achieving this farm gate price in the long term for a broadacre wattle seed crop.

2.1 Wattle Seed Harvester R&D Needs

Any harvester has the same functional areas

- Select
- Gather
- Control
- Detach
- Transport
- Platform

These functional areas are arranged in any order, and the processes that occur in each area are the keys to the operation of the harvester.

Plant characteristics also have a major effect on harvesters. Plant shape and habit, height uniformity, location of the harvestable components, length of the harvest window, fragility of the seedpods, and spacing of plants in and between rows will all impact on the harvester. The terrain and soil type, length of rows, access for grain transport, distance between stands, clearance from fences and ditches will all affect the design of the platform.

A wattle seed harvester would have to be designed to maximize the rate at which it covers the crop area to reduce the cost/tonne of harvesting the seed. Machine width, ground speed and field efficiency are the variables that control the areal rate.

Machine width is controlled by the need to manoeuvre within the available space, and for a machine that will be harvesting well above ground level, by considerations of the weight of the front and the stability of the machine. The 4m suggested above may be a reasonable limit.

Ground speed will firstly depend on the rate at which the crop can be selected, gathered, controlled, detached and delivered to a grain bin. Selection, gathering and control depend essentially on the plant form and the location of the seedpods within that form. Detaching the pod and seeds is a process that can be achieved in a variety of ways, but this function will generally be somewhat independent of the selection, gathering and control components. It can therefore (in the first instance) be researched independently. On the other hand, the finger harvester discussed in the report selects, gathers, controls and detaches with one component.

Ground speed may also be limited by other factors to do with the platform, operator comfort, the terrain and soil types, and the type of ground drive.

Field efficiency is partly a result of the reliability of the harvester components and their ability to function over a range of conditions, and the organization of the infield operations. Grain harvesters have a field efficiency of about 0.75 to 0.8, and they are well understood, well developed, and the infield operations are routine. The field efficiency of 0.5 suggested for a newly developed wattle seed harvester operating across a range of conditions is about right, and will not improve very much in the short term. It may even get worse.

It is obvious that there major interactions between these factors and the crop, and that a wattle seed harvester R&D program needs to be integrated with at least the ongoing silvicultural investigations, operational modeling and market analyses.

As noted in the introduction, a wattle seed harvesting operation would have access to existing grain harvesting infrastructure, and this is a major advantage.

2.2 Harvesting Aids

There is very probably real scope for the development of truck based and/or hand held harvesting aids to assist with the gathering of wattle seed intended for the bush food market, and to trial prototype machine harvesting components.

This route offers low cost and rapid assessment of potential harvesting processes, and would provide a base of experience and practice on which to base harvester development.

3 Biomass Harvesting

It has been noted in the report that an industry that depends on one raw material and one end product, wattle seed flour in this case, carries a high degree of risk. Multiple products offer a less risky route to viability, and the potential products identified in Table 1 of Appendix 1, except for wattle seed production, all imply that the *Acacia* biomass is harvested.

This further suggests that a biomass harvesting system should have a higher priority than a wattle seed harvester, bearing in mind the need for an infrastructure to accept and process the biomass.

Biomass harvesting is all about growing a crop to maximize the mass available, in such a way as to simplify its harvest, and then harvesting that mass and delivering it to a processing plant at the highest rate possible.

Again, to give some perspective on what has to be achieved, we can consider sugar cane as an obvious example of this type of crop. The plants are selected to give the maximum yield when mechanically harvested, they are planted in rows spaced to fit the harvester, the row profile is formed to suit the harvester, infield transport is specialized and highly developed, and there is a dedicated rail transport infrastructure from the farm to a centrally located processing facility. The entire system is controlled by the mill, so that deliveries are scheduled and made in a timely fashion.

After more than 40 years of mechanical harvesting and ongoing development within the industry, cane is delivered **into the mill** for an overall growing and infield harvesting and transport cost of about \$22/tonne. The mill then provides all the off-farm transport costs and all the processing costs to convert seven tonnes of cane into one tonne of sugar, which sells for about \$200/tonne.

If biomass for energy is viable at a **factory gate price** of \$25/tonne (net of stumpage to the farmer), then there is a substantial challenge in developing a biomass harvesting and transport system that can do this, within a broadacre context, for the same cost as that of cane harvesting. There is the possibility that biomass products other than energy will be of substantially higher value, offsetting the harvest and transport costs, and it is this prospect that drives biomass agroforestry.

3.1 Biomass harvester R&D Needs

The biomass harvester has the same functional areas as the wattle seed harvester, but the “detach” function is followed by a chipping function. The weight of evidence across a wide range of agroforestry industries based on small trees, is that chipping on a continuously moving harvester offers the only route to a viable harvesting system.

The biomass harvester therefore will have a chipper, preceded by means for gathering, selecting, controlling and detaching the trees.

The conventional chipper, in either the drum or disk configuration, is a very mature technology, with only marginal improvements now being made. They are heavy, require large amounts of power, and have been optimized to provide quality chips for pulping.

In-forest chippers are centrally located and are used to chip whole logs and branches. They have installed powers that are perhaps 10 times the power required to perform the actual chipping. I have made an analysis of a recent paper by Spinelli and Hartsough (2001) that reports on data collected from 100 in-forest chipping operations in Italy, and have shown that it is the inefficiency of the materials handling that leads to such a mis-match between the size, weight and power of chippers and the task that they actually perform.

A biomass harvester has to be mobile, so its overall mass has to be minimised. The implications of this fact are, in part, that the chipper has to be as light as possible, and have minimum installed power. Further, the data of Spinelli and Hartsough show that this can only be achieved if the material handling within the harvester (the select, gather, control and detach functions) is as efficient as possible.

The chipper will also need some attention. I have noted that current configurations have been optimized to chip large logs and yield quality chips. This occurs at the cost of extra power and cutting forces over the power and forces required to simply comminute wood by chipping. There is a large body of research evidence that shows that the blade angles and configurations currently used in disk and drum chippers are not as energy efficient as other blade angles and configurations that have only been achieved in a research context.

I have recently proposed a method for constructing a drum chipper that allows blades to be set at non-conventional angles, thereby enabling more efficient chipping of wood for biomass purposes (Harris, 2002). It is well adapted for use in whole tree chipping.

This is a proposal that needs further support and funding to develop the ideas and assess (at least) whether it can chip trees more efficiently than a conventional chipper.

I have also been involved in a project for a client in Western Australia, to investigate and propose a biomass harvester for mallee trees. These proposals have been completed, but as yet no decision has been made on whether to commit the large funds require to continue with the development.

(Discussions about a mallee harvester commenced almost three years ago, which gives an indication of the lead-time required to create and negotiate a project proposal).

A biomass harvester for *Acacias* would have a very similar configuration and capability to a biomass harvester for mallees. It makes obvious sense to look at whether the JVAP, in its consideration of an *Acacia* industry, should or could contribute to the development of the mallee harvesting system.

4 Conclusions

This assessment of the harvesting needs for an *Acacia* based agroforestry industry has concluded:

1. There is technical risk in developing a wattle seed harvester to meet the proposed specification, and there is a further marketing risk in achieving this farm gate price in the long term for a broadacre wattle seed crop.
2. It is obvious that there are major interactions between harvester functions and the crop, and that a wattle seed harvester R&D program needs to be integrated with at least the ongoing silvicultural investigations, operational modeling and market analyses.
3. The development of handheld harvesting aids offers low cost and rapid assessment of potential harvesting processes, and would provide a base of experience and practice on which to base harvester development.
4. A biomass harvesting system should have a higher priority than a wattle seed harvester, bearing in mind the need for an infrastructure to accept and process the biomass.
5. The chipper configuration proposed by Harris needs further support and funding to develop the ideas and assess (at least) whether it can chip trees more efficiently than a conventional chipper.
6. The JVAP, in its consideration of an *Acacia* industry, should consider whether it should or could contribute to the development of the WA mallee harvesting system.

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Appendix 1: Workshop Program



WATTLE SEED WORKSHOP

12 March 2002

SCARTH ROOM

University House, Australian National University

8:45am - 4pm

- 8:45am** Coffee
- 9:00am** Call to Order and administrative matters: Peter Chudleigh, Agtrans Research
Welcome and Introduction: Roslyn Prinsley, RIRDC
- 9:15am** **Session 1:** Chairperson, Roslyn Prinsley, RIRDC
Presentation of 3 Keynote Papers of approximately 12 minutes each. The purpose of this session will be to provide background to the workshop.
- “Potential for a wattle seed industry” Sarah Simpson, Agtrans Research.
- “Building a large-scale wattle seed industry” Graeme Olsen, Olsen & Vickery.
- “The wattle seed industry alliance” Charles Littrell, Wattle Seed Industry Development Alliance.
- 10 minute discussion across the three papers
- 10:00am** **Session 2:** Chairperson, Roslyn Prinsley, RIRDC.
The purpose of Session 2 is to introduce important factors that may affect the development of a wattle seed industry.
- 10 minute presentations:
1. Tim Vercoe, CSIRO Tree Seed Centre, Canberra
Topic: “Genetic factors influencing a wattle seed industry and scope for genetic improvement”.
 2. David Topping, CSIRO Health Sciences and Nutrition, Adelaide
Topic: “Opportunities and constraints for developing large scale markets for wattle seed and its components with specific focus on health and human nutrition factors” eg. anti-nutritional factors, nutraceuticals and therapeutics, regulatory aspects.
- 10 minute discussion across first two presentations

Break for morning tea 10:30 – continue Session 2 at 10:50

3. Ragini Wheatcroft, CSIRO Food Science Australia, Werribee, Vic
Topic: “Opportunities and constraints for developing large scale markets for wattle seed and its components with specific focus on food processing factors”
eg. flavours, carbohydrate and protein markets, regulatory aspects.
4. Tony Schlink, CSIRO Livestock Industries, Perth, WA
Topic: “Opportunities and constraints for developing wattle seed and its joint products as animal feeds”
5. John Bartle, CALM, WA
Topic: “The relative water balance/sustainability impacts of a wattle seed industry compared with other possibilities”
6. Bill Kerruish, Honorary Research Fellow, CSIRO Forestry and Forest Products, Canberra
Topic: “Conceptual and development issues for harvesting wattle seed”

15 minute discussion across four presentations

11:45pm **Session 3:** Facilitator, Peter Chudleigh, Agrans Research.

Plenary session to:

- discuss the prospects for developing a wattle seed industry and the major challenges
- identify the issues to be discussed in working groups in Session 4.

12:30pm Lunch

1:15pm **Session 4:** Facilitator, Peter Chudleigh, Agrans Research.

Working groups on about 5 key topics. The topics will be decided by the workshop participants before lunch. The working groups will provide information on ‘the next steps’ necessary within different topics.

2:15pm Groups to report back on their discussions and make recommendations for further work

2:55pm 5 minute break to grab a coffee and return to final plenary session

3:00pm **Session 5:** Facilitator, Peter Chudleigh, Agrans Research.

Plenary session – the purpose of which will be to assemble views on future prospects, frame overall priorities, and develop recommendations on ‘the next steps’ to be taken.

3:50pm Close and wrap-up – Roslyn Prinsley, RIRDC

Appendix 2: Profiles of Speakers

Sarah Simpson, Agtrans Research, Brisbane

Sarah Simpson graduated in Science (Australian Environmental Studies) where she majored in environmental planning processes, environmental policy and economics, and land and water processes. Sarah completed a Post Graduate Diploma in Agricultural Economics in 1998 and joined Agtrans Research in early 1999. Since joining Agtrans Research Sarah has been involved in research on a variety of topics including the study for RIRDC on the potential for a wattle seed industry in the low rainfall areas of Australia.

Graeme Olsen, Olsen & Vickery, WA

Graeme Olsen is a private consultant from Western Australia. He is working on the NHT Search project, to find native woody plants with potential for development as large-scale commercial crops in Australian dryland agriculture.

Graeme's background is in agricultural science, specialising in agricultural economics. He has worked on beach erosion, mine rehabilitation, pollution control and forestry policy, and has finally returned to agriculture.

Charles Littrell, Wattle Alliance Pty Ltd

Charles Littrell is an independent investor and entrepreneur. He is a director and substantial shareholder in Australian Native Produce Industries Pty Ltd, a leader in the native food plant industry. For many years Charles was an executive at Westpac Banking Corporation, where he was variously that Bank's head of group strategy, manager of the Australian deposits and investment business, and Director of Westpac Corporate Finance. Charles's qualifications include a B.A (economics) from Yale University, and a Master of Economics (First Class Honours) from the University of Sydney.

Tim Vercoe, CSIRO Tree Seed Centre, Canberra

Tim Vercoe is the officer in charge of the Australian Tree Seed Centre, part of CSIRO Forestry and Forest Products. The Centre has played a leading role in the domestication of the Australian flora for the last 40 years. Each year staff of the Centre respond to more than 2000 enquiries about the use and adaptability of native trees and shrubs from researchers, community groups and individuals in Australia and abroad. Most of the Centre's exploration and evaluation work is done in collaboration with land owners and groups interested in commercial and environmental revegetation work. Tim's main interests are in forest genetic resources and in information systems to support exploration and evaluation.

Ragini Wheatcroft, CSIRO Food Science Australia, Werribee, Vic

Ragini Wheatcroft is the Section Leader for Bioprocess Technology with Food Science Australia. The Bioprocess technology group innovates for the food industry through an integrated approach to R&D in process and separations technologies, waste utilisation, and functional ingredient technology to produce high value food and ingredients. The group also develops rapid in line or at line analytical processes for food processing control. Ragini's major research interests are value addition to byproduct streams and functional foods.

David Topping, CSIRO Health Sciences and Nutrition, Adelaide

David Topping is a Senior Principal Research Scientist with the CSIRO Division of Human Nutrition, as well as a Clinical Senior Lecturer in Biochemistry at Flinders University of South Australia. David's major professional activities since 1993 have included being Program Manager for the Gastrointestinal Health and Colon Cancer Program, and Scientific Co-ordinator for the Nutrition Enhancement Program. David's principal research focus is on Dietary carbohydrates (fibre, resistant starch and oligosaccharides) and dietary fats (especially n-3 fatty acids) and gut health.

Tony Schlink, CSIRO Livestock Industries, Perth, WA

Tony's interest in *Acacias* is an extension of his role in Townsville with the CSIRO Division of Tropical Animal Production. He was involved in a project to determine the nutritive value of 'new' tropical pasture and shrub/tree species. The AWC also funded a project to introduce legumes to the clay soils of western Queensland. Currently his major research interests are in improving the quantity and quality of wool production. *Acacias* may play a part in this by providing feed during the annual feed gap as well as reducing the water table.

John Bartle, CALM, WA

John Bartle is an agricultural scientist and Manager of the Farm Forestry Unit in the Department of Conservation and Land Management in Western Australia. He has a background in research on revegetation to manage salinity and rehabilitate degraded land. His major activity in recent years has been development of commercial tree crops for use as an integral part of sustainable agricultural systems in the low rainfall wheatbelt agricultural regions. He has been involved in the oil mallee project in WA since its inception in 1993, he leads the 'Search' project that aims to objectively select native species with potential for commercial development and he leads the woody germplasm subprogram in the Salinity CRC.

Bill Kerruish, Honorary Research Fellow, CSIRO Forestry and Forest Products, Canberra

Bill Kerruish is an Honorary Research Fellow with the Forest Technology Program of CSIRO Forestry and Forest Products. He has research experience in forest operations and his major projects have included:

- the mechanisation of plantation thinning including the development of the Windsor harvester
- the Young Eucalypt Program that explored options for the management of regrowth eucalypt forests
- Inaugural director of the Forest Technology Program.

His business interests include the manufacture and marketing of stem injection equipment for thinning young forest and the removal of woody weeds.