Broadscale production of wattle seed to address salinity: potential and constraints

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SUMMARY

Edible *Acacia* seed, or 'wattle seed', is a potential commercial crop that could provide land management benefits in low- to medium-rainfall agricultural areas in southern Australia. A review of wattle seed on behalf of the Joint Venture Agroforestry Program found that large markets for food ingredients are out of reach for existing wattle seed production systems, due to the high harvesting cost. Lowering the cost to a level competitive with other large-scale food crops will require development of a new production system that integrates crop layout, harvesting method and species selection. An efficient harvester is likely to have many features in common with modern cereal crop headers: light weight, continuously moving, straddling the crop, and a wide intake to maximise the tonnage harvested per operating hour. Species best suited to such a harvesting system would be short, compact and erect, bear their seeds near the top of the plant, have a high ratio of seed production to vegetative growth, and be suited to growing at high density. A plant with these characteristics would be very different from the tall, spreading shrubs currently used for edible seed production. A first step towards building a large-scale wattle seed industry would be to explore the abundant genetic resource of this genus for species with desirable characteristics for low-cost production.

INTRODUCTION

The water use of annual crops and pastures in the low- and medium-rainfall agricultural zones of southern Australia is out of balance with rainfall, resulting in a slow filling of soil profiles with excess water and, in many areas, a remobilisation of salt stored in the soil. As a result, large areas of the southern agricultural landscape are at risk of developing dryland salinity. The area likely to be affected in south-west Western Australia is estimated to be up to 30% (State Salinity Council 2000).

Of the many potential solutions to this problem, a key one is to reduce the leakage of rainfall past the shallow root zone of agricultural systems based on annual plants, by increasing the area of deeper-rooted perennial plants on farms (Hatton and Nulsen 1999). The extent to which perennial plants might be deployed in agriculture depends on the goal. Options include:

- slowing the rate of spread of salinity and delaying the onset of symptoms (least ambitious),
- halting the spread of salinity,
- reclaiming saline land (most ambitious).

The scale on which perennial plants are needed in order to control recharge also varies from place to place, due to hydrological variability and complexity. Where landscape relief is low, or soils have low permeability, lateral movement of groundwater is slow compared to the rate at which soil profiles are filling with excess rainfall. This leads to the conclusions that strategic placement of small areas of perennial vegetation would usually be ineffective in controlling salinity, and that a high proportion of the agricultural landscape (in some areas as much as 80%) would have to be revegetated to achieve that aim (George *et al.* 1999; Hatton and Salama 1999).

The National Land and Water Resources Audit (2001) gives a broad estimate of the likely need for perennial vegetation in agricultural areas: '. . . for effective reduction in recharge there may need to be 30–50% reforestation in a catchment (and even more if trees are to be harvested).' Based on this estimate, between 15 and 25 million hectares of perennial plants could be needed in southern agricultural regions. Such large-scale use of perennial plants in agricultural systems is likely only if the bulk of those plants have a commercial use (Bartle 2001) and produce financial returns similar to existing agricultural crops.

Acacias are strong candidates for development into new perennial agricultural crops, as they have potential to produce a wide range of commercial products, including edible seeds. Their favourable attributes include:

- large number of species,
- adaptation to Australian conditions,
- wide variability between and within species, enhancing the prospects for selecting suitable germplasm for commercial development, and
- potential to enhance nature conservation goals if appropriate species are planted in suitable locations.

The biological attributes of *Acacia* that favour their development as crop plants and the range of potential commercial uses for *Acacia* are discussed elsewhere in this proceedings (Bartle *et al.*).

Edible *Acacia* seed, or 'wattle seed', is a potential commercial crop that could provide part of the perennial plant component of a new Australian agriculture. It has many attractive elements as a commercial crop:

- it has a long history of use by indigenous Australians as food (Devitt 1992, cited in Harwood 1994),
- a small commercial wattle seed industry is already in operation (Maslin *et al.* 1998),
- grains and seeds are high-value products that lose only a moderate percentage of their value in transport costs when transported long distances to markets,
- grain production and export is a familiar industry for Australian farmers, and
- an Australian grain handling infrastructure is well developed.

Maslin *et al.* (1998) reviewed the potential of Australian *Acacia* species for wattle seed production. Based on plant features that would suit commercial production and reports of their utilisation by Aborigines, they listed 47 species considered suitable for cultivation in the semi-arid agricultural region of southern Australia.The 18 species considered to have the best prospects were grouped into three categories:

Most promising species: *A. murrayana*, *A. victoriae*

Other promising species: *A. jennerae*, *A. microbotrya*, *A. pycnantha*, *A. retinodes*, *A. rivalis*, *A. saligna*

Lesser-known species: *A. anthochaera*, *A. blakelyi*, *A. scirpifolia*, *A. brumalis*, *A. calamifolia*, *A. confluens*, *A. hakeoides*, *A. hemiteles*, *A. prainii*, *A. subrigida*.

WATTLE SEED REPORT – BY AGTRANS RESEARCH

The Joint Venture Agroforestry Program[1] commissioned Agtrans Research[2] to assess the technical, commercial and economic basis for developing a large-scale wattle seed industry in Australia. A report on this project, *Wattle Seed Production in Low Rainfall Areas* (Simpson and Chudleigh 2001) is available from the Rural Industries Research and Development Corporation, publication number 01/08.

A brief summary of the findings of this study is presented below.

[1] The Joint Venture Agroforestry Progam (JVAP) is coordinated and supported with funding by three Australian government research and development corporations (RDCs) – Rural Industries (RIRDC), Land and Water Australia (LWA), and Forest and Wood Products (FWPRDC).

[2] Agtrans Research is a private research consultancy, PO Box 385, Toowong, Queensland 4066. Email: agtrans@powerup.com.au.

Potential markets

The high-value bush food market has potential for significant growth but is unlikely to reach a size that would require broadscale dryland production of wattle seed. To achieve that goal, with its accompanying land management benefits, would require expansion into larger, lower-value markets such as specialty flours for use in bread, biscuits, cakes and pasta. To expand further, to become a large-scale industry comparable to other mainstream cereal crops, would require expansion into large, price-competitive markets for generic food ingredients such as starches, vegetable protein and vegetable oils.

Nutritional value

There is limited information available on the nutritional value of wattle seed. The results of analyses of whole seeds (including seed coats) of a small number of species indicate that wattle seed has a protein content of about 20%, a fat content of about 5% (mostly unsaturated), a carbohydrate content of about 40% (mostly starches), and a dietary fibre content of approximately 30%. These attributes may make wattle seed an attractive source of food ingredients but further work is needed to investigate their nutritional constituents in more detail, test the nutritional value of a wider range of species, and quantify the variation within species.

Harvesting

Harvesting is the largest impediment to lowering the cost of producing wattle seed. Three methods were assessed– butt shaking, finger stripping, and whole biomass harvesting. Calculations of the cost per harvested tonne assume an average annual seed production of 1.25 tonnes per hectare:

Butt shaking involves mechanically shaking each tree to dislodge pods and seeds into collecting trays. Harvest cost of this method is estimated to be $3,125 per hectare, or $2,500 per tonne of seed. This method suffers the disadvantage of being a stop-start operation, limiting the scope for reducing its cost by further development. It also requires single-stemmed tree architecture, and may not be effective at dislodging lightweight pods at the extremities of tall, flexible *Acacia* trees or shrubs.

Finger stripping involves combing pods from the outer foliage of plants. This is a much cheaper harvesting option, at an estimated cost of $750 per hectare, or $600 per tonne of seed, because it could be incorporated into a machine that moved continuously along rows of trees. This method would be suitable for species that carried most of their seed pods on the outer edges of the canopy.

Whole biomass harvesting, followed by separation of the pods and seed, is estimated to cost $500 per hectare, or $471 per tonne of seed (assuming a harvest yield every four years of 85% of 1.25 tonnes per hectare).

These cost estimates are speculative, as considerable development work would be needed to optimise harvest machinery for particular species, or groups of species, layouts and silvicultural methods.

Species selection criteria

For commercial seed production *Acacia* species would have to be selected and developed to maximise harvesting efficiency. Critical factors include suitable plant architecture (which depends on the harvest method), high seed yield, regular seed production and a long harvest window.

In addition, suitable species would have to be non-toxic, have desirable nutritional characteristics, be adapted to a range of climates and landscapes, be easy to propagate and manage, grow well in an agricultural setting and, if possible, produce valuable co-products.

Although it is likely that any *Acacia* species would improve the water balance if grown as a crop in place of annual crops or pastures, there may be substantial differences between species. Therefore, root architecture and water usage may also be used as selection criteria to maximise the land management benefits from any new crop.

Economics

The report includes an economic analysis of a production system with 625 trees per hectare in a plantation layout, under each of the three harvesting systems described above.

Assumptions used include:

- discount rate = 10%
- duration of project = 12 years
- seed production = 1.25 tonnes per hectare (625 trees x 2 kg per tree)
- seed production starting in year three and reaching a maximum in year five; for the 'whole biomass harvesting' option, harvesting is carried out every four years, when seed production is 85% of its maximum
- establishment cost = $380 per hectare
- annual management cost = nil
- market price for seed = $1,000 per tonne (at farm gate)
- harvesting costs as above: $3,125 per hectare for butt shaking, $750 per hectare for moving fingers, and $500 per hectare for whole biomass harvesting.

Under these assumptions, a seed production enterprise based on butt shaking was very unprofitable, while enterprises using finger stripping or whole biomass harvesting produced positive returns, comparable with returns from growing wheat.

The sensitivity of these results to some of the assumptions used in the economic analysis were tested. It was found that the profitability of wattle seed production is influenced strongly by seed yield, harvesting cost and market price. Break-even values for each of these factors are given in Table 1.

For all three factors, break-even values for the butt shaking method of harvesting are well outside those assumed in the economic analysis, by a factor of approximately three, while for both finger stripping and whole biomass harvesting, break-even values are inside the range needed for profitability.

TABLE 1
Break-even values for seed yield, harvest cost and market price (at farm gate) for wattle seed.

	HARVEST METHOD		
	BUTT SHAKING	FINGER STRIPPING	WHOLE BIOMASS
Min. yield per tree (kg/year)	5.7	1.4	1.0
Max. harvest cost ($/kg)	1070	1070	1027
Min. market price ($/t)	2870	710	500

Note that this analysis assumed a farm gate price of $1,000 per tonne for wattle seed, a price that may be sustainable in a small-scale industry but not in large markets in competition with other large-scale crops.

Research and development needs

Four key strands of research and development required for the development of a large-scale wattle seed industry were identified:

- food production and nutritional characteristics–determining the nutritional composition and behaviour of wattle seed, their pre-processing requirements, and their performance in industrial food processing
- market research–to improve understanding of potential volumes and prices of different market sectors, and the strengths and weaknesses of competing products
- economic analyses–refinement of the assumptions used in this report, and extension of economic analyses to other production systems
- seed production, harvesting and sustainability–exploration of technical issues ranging from species selection and establishment through growing systems to harvesting and sustainability issues.

Summary of conclusions

1. Bush food markets are growing, but will always be a niche opportunity, providing only limited land management benefits.
2. Large markets for food ingredients may be accessible to wattle seed and could stimulate large areas of dryland *Acacia* cropping, but current production systems are not competitive due to their high cost, harvesting cost being the main impediment. To compete in large-scale markets, production costs would have to be well below $1000 per tonne, perhaps as low as $200. Production costs in this range are possible only if low-cost harvesting systems are developed. Finger harvesting and whole biomass harvesting have the most potential.

3. Yield, harvest cost and market price are the three critical issues affecting profitability.
4. Too little is known at this stage to allow a reliable assessment of the potential of wattle seed in low rainfall areas. The critical research and development required to establish this industry's potential were identified in the study (listed above).

DEVELOPMENT OF A LARGE-SCALE INDUSTRY

The Agtrans Research report summarised above provides a starting point for further exploration of the issues that confront the development of a large-scale wattle seed industry. Some of these issues–food safety, market price and low-cost production systems–are discussed briefly below. Other important issues such as nutritional properties of wattle seed, their suitability for various uses and marketing issues are not dealt with here, although all are critical to the development of a large wattle seed industry.

Food safety

New crops developed for human consumption require a cautious approach, to ensure that new foods present no unacceptable health risks. Seed of some species of *Acacia* were eaten by Australian Aborigines as part of their traditional diet (Maslin *et al.* 1998), and are generally regarded as safe, especially if heated to denature anti-nutritional factors (Simpson and Chudleigh 2001).

Hegarty *et al.* (2001) reported that most widely-used bush foods are likely to be safe if consumed in modest quantities as part of a mixed diet, and if handled and prepared in ways that avoid or destroy any toxic contaminants or constituents, where applicable. However, where a minor food plant becomes used in much greater amounts in the diet, or a native plant not previously used for food is added to the diet, then food safety must be assessed more closely. This could be the situation if some wattle species became more widely eaten, or if others were newly developed as seed crops.

Natural variability in newly cultivated species and the wide range of individual human tolerance to different chemical compounds may result in isolated cases of illness, even in crops that are safe for most of the population (Hegarty *et al.* 2001). For a new food crop, these issues should diminish in time, as the crop becomes more uniform through plant breeding, and as susceptible sections of the population become aware of their susceptibility to the new food and avoid it.

Increasing the scale of wattle seed production

The current edible wattle seed industry is very small. Annual commercial production is between 12 and 20 tonnes, and the price paid to producers is in the range $12,000–$25,000 per tonne for clean seed (Simpson and Chudleigh 2001). Production costs are high, most seed being harvested manually from natural stands of *Acacia victoriae*. A few private growers harvest seed from small plantations, some using manual methods and some developing and testing various mechanised systems.

What changes would be required for wattle seed to expand from its current position as a boutique industry into an industry of sufficient size to produce significant land management benefits? A brief look at existing large-scale grain crops is useful.

Wheat is at the opposite end of the spectrum to wattle seed. It is the dominant crop in southern Australia and is grown on large areas at low production cost. About 20 million tonnes of wheat are harvested in Australia each year (about 3% of global production), of which 70–80% is exported (ABARE 2001). Growers receive about $160 per tonne at the farm gate (ABARE 2000). The wheat industry has benefited from sustained, high levels of investment in research and development, and operates in highly mechanised production systems.

Other large-scale crops have features similar to wheat. Table 2 contains details of all Australian dryland crops with annual production over one million tonnes. With the exception of oats, over half of Australia's production of these crops is exported. Average export prices (1995–2000) were approximately $200 per tonne, apart from canola at $386 per tonne.

TABLE 2
Statistics for large-scale Australian dryland crops (FAO 2002). Data are averages for 1995-2000 inclusive.

CROP	YIELD (t/ha)	PRODUCTION (Mt)	EXPORT (Mt)	EXPORT PRICE (A$)
Wheat	1.8	21.7	15.2	227
Barley	1.8	5.9	3.2	198
Oats	1.6	1.6	0.2	183
Lupin	1.1	1.5	0.8	221
Canola	1.3	1.3	0.8	386

It is likely that wattle seed would have to conform to a similar pattern if it were to become a large industry. Most of its production would have to be exported and its price would reflect its competitive position relative to other commodity crops. Features that give wattle seed an advantage in small markets (novelty, unique flavour, and special dietary features) would be of little or no value in commodity grain markets, where uniformity, cost, nutritional content and performance in food processing are more important criteria.

The task of marketing large tonnages of wattle seed would be challenging. If *Acacia* seed crops provided only a modest percentage of the total area of perennial plants needed to control salinity (say 10%, or 2 million hectares), then the annual production of seed would be about 2.5 million tonnes, based on an estimated production rate of 1.25 tonnes per hectare (Maslin *et al.* 1998). A harvest tonnage of this size would make the wattle seed industry larger than Australia's canola industry, half the size of the barley industry and about one eighth the size of the wheat industry.

The development of a wattle seed industry on this scale (or larger) would be a major undertaking and would be achievable only if wattle seed could overcome a number of commercial hurdles, including:

- acceptance into large-scale markets for food ingredients, both domestic and export
- better quality or lower price than competing products
- an attractive return to growers.

Reducing the cost of production

The remainder of this paper deals with one of the commercial hurdles listed above – the need to reduce the cost of production of wattle seed.

Production costs for existing large-scale, broad-acre Australian crops provide useful guidance. These crops are grown over large areas, benefit from economies of scale, and are produced by low-cost methods that include direct seeding, continuous harvesting by wide, high-speed, light-weight machinery, and bulk handling of harvested seed. Using wheat production in Western Australia as an example, the cost of production using these methods is about $130 per hectare to grow the crop, and a further $30 per hectare to harvest it, based on contract prices plus materials, but excluding overheads and GST (drawn from a variety of unpublished sources). Therefore, for a crop yield of 1.7 tonnes per hectare (the average wheat yield for Western Australia from 1996 to 2000; ABARE 2001), the on-farm cash cost to produce each tonne of wheat is about $75 for growing and $20 for harvesting.

If wattle seed were to be grown and sold in large quantities it would have to be competitive with other large-scale commodity crops, and be produced in similarly low-cost farming systems. Some elements of low-cost production are easily achievable. For example, direct seeding acacias should be relatively straightforward. For most species of interest, the seeds are large enough to be handled efficiently by conventional seeding equipment, and the seeds germinate easily and reliably after pre-treatment. Similarly, bulk handling of wattle seeds should be possible using the grain industries' existing infrastructure, with little or no modification.

Harvesting is more problematic. None of the harvesting methods assessed by Simpson and Chudleigh (2001) for use on rows of tall shrubby acacias is likely to match the harvesting cost of headers used in cereal cropping, regardless of how much development effort is applied, because of the difference in their fundamental principles of operation. Therefore, further refinement of existing horticultural approaches to wattle seed production are unlikely to lead to the development of a farming system that can produce millions of tonnes of wattle seed at prices competitive with those of other commodity crops.

To lower the cost of wattle seed production to a competitive level is likely to require the development of a new, efficient production system. Three integrated elements of efficient systems are:

- crop layout
- harvesting method
- species selection.

Each of these elements is dependent on the choices made for the others. They are discussed briefly below.

Crop layout

Conventional long-term plantations are unsuited to perennial crops in medium- to low-rainfall agricultural areas because of the likelihood of reduced productivity due to competition for water, and the risk of death from drought. Instead, dispersed layouts have been proposed for new perennial crops in this rainfall zone. They include:

- alley farming, with one or more rows of trees in long belts, separated by wide alleys of annual crops or pastures (Stirzaker and Lefroy 1997);
- phase farming, in which a whole paddock is planted with a crop of close-spaced perennial plants (Harper *et al.* 2000). The perennial plants are removed after a number of years and replaced with a phase of annual crops and pastures. The duration of the perennial phase would depend on many factors, including the product(s) being produced, plant growth rate, water use, management requirements, plant longevity, site factors such as annual rainfall and soil water storage, and economic factors such as optimisation of crop returns within the perennial phase, and optimisation of the profitability of the entire farming system.

Both of these layout types could be used for low-cost wattle seed production, but with some provisos. In both cases, the species used would have to be short-statured to allow the crop to be straddled by a harvester and be suited to growing at high density. For alley farming, the *Acacia* belts would have to be at least one harvester width wide, to enable the harvester to collect a high tonnage of seed per operating hour. If wider than a single harvester width, belt width should be a multiple of harvester width to maximise harvesting efficiency.

Harvesting method

To maximise the rate of collection of seed from low yielding crops (1.25 tonnes per hectare), a wattle seed harvester would be likely to have many design principles in common with modern cereal crop headers, including high ground speed and manoeuvrability, and a wide front. It is likely that the machine would:

- straddle the crop, to minimise the required ground speed while maximising the number of plants that could be harvested simultaneously,

- move continuously, to maximise the amount of seed collected per operating hour, and
- remove only pods and seed, to minimise the machine's weight, harvesting effort required, and the amount of superfluous material harvested.

Species selection

The harvesting principles described above would require a very different plant architecture from the types of acacias currently considered suitable for edible seed production. From a harvesting perspective, features that would enhance the suitability of an *Acacia* species for large-scale, low-cost wattle seed production include:

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

In addition, there are many other criteria for selecting new crop species that are unrelated to harvesting. They 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 many factors related to management in a farming system, including palatability to stock, toxicity to stock, weed risk, nitrogen fixing ability, and tolerance of herbicides and insecticides.

Combined biomass and seed crops

The possibility of developing new *Acacia* crops that produce both edible seed and biomass for industrial uses appears attractive. However, the requirements for harvesting biomass and those for harvesting seed are very different, and it would be difficult to design a harvester that performed both tasks efficiently (Richard Giles, pers. comm.). In addition, the feedstock requirements of most biomass industries would demand year-round harvesting, not just at seeding time. A more likely scenario is that some *Acacia* species may be developed as large-scale crops for industrial uses. If these species also produced edible seeds, then some seed would be collected opportunistically by dedicated biomass harvesting machines during harvesting operations at seeding time, and could be separated and sold as a by-product of biomass harvesting.

Suggested way forward

The preceding discussion leads to the conclusion that the development path to be followed for an edible wattle seed industry depends on the target size for the industry. If it is to grow from its present niche status into an industry supplying small or medium-sized markets at prices in excess of $500 per tonne, then a suitable approach may be to refine existing growing and harvesting techniques, and select and breed new cultivars from within the species already identified as having potential for edible seed production.

However, if a more ambitious goal is set–to develop a large wattle seed industry that is competitive in global commodity markets–then a different development pathway is needed, in order to achieve the low cost of production that is essential for success in those markets.

Critical 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.

The great diversity within the *Acacia* genus (and within many of its species) offers hope that this development pathway could succeed. 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.

Before such a plant breeding program is started, an understanding is needed of genetic diversity within the target species. There are likely to be differences in genetic variation between species. For example, Moran *et al.* (1992, cited in Ahmed and Johnson 2000) found distinct genetic variation in *Acacia holosericea* (three isozyme races) with corresponding differences in morphology and growth, but no variation between 15 populations of *A. cowleana*.

Plant breeding work on Australian native crop plants such as *Acacia* is insignificant in comparison with a crop such as wheat (Ahmed and Johnson 2000). All major agricultural crops have undergone unconscious selection, leading 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. Perhaps as little as a decade would be needed to transform a representative of one of Australia's best known genera into a potential new food crop of global significance.

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