Economic potential from Western Australian *Acacia* species: secondary plant products

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SUMMARY

Widespread planting of native Western Australian trees may contribute to resolution of salinisation problems in parts of the wheatbelt and contribute to an overall increase in biodiversity. For these approaches to succeed, however, they must provide income for farmers in the area. Among the most common and most promising tree species in Western Australia are wattles, Australian species of *Acacia* subgenus *Phyllodineae*. Wattles produce a number of interesting classes of secondary compounds, some of which have potential as foods or food additives, whereas others have potential industrial applications. Water-soluble polysaccharides, known commonly as 'gums', are common constituents of these *Acacia* species. There is a significant demand for these products because of long-term shortages–a situation that appears unlikely to change in the near future. Gums are important components of food products and are often used to microencapsulate not only particles of food mixes and pharmaceuticals but also hazardous materials such as insecticides, herbicides, detergents and dyestuffs. Although gum substitutes are available, none of these gums has the desirable physical properties of gum arabic or gum acacia, now primarily derived from one African species of *Acacia*. Some Australian *Acacia* species also produce gum of excellent quality, but new methods of gum induction, harvest, extraction and purification must be perfected before they can compete in the world market. Tannins also are found in many Australian *Acacia* species. Mostly these compounds are used for production of leather but they have a range of other uses. In the past, Australia was a major leather producing and exporting country; the ready availability of good quality, inexpensive tannins might put this again within reach. Plants rich in tannins may not be as suitable for gum production, because the presence of tannins in gums decreases the value of the latter. However, new techniques make it possible to separate gums and tannins more efficiently.

Triglycerides and fatty acids are common components of the seeds of wattles and have a range of non- uses in food. Cultivation and harvest of the seeds can provide edible oils and protein-rich press cake for both human and domestic animal consumption. Other wattle compounds such as resins (diterpenes) probably have limited economic potential. The distribution and chemistry of saponins (triterpene or steroid glycosides) is incompletely known among wattles but some of these compounds appear to have profound biological activity. Although many compounds found in wattles are beneficial, some species contain potentially harmful substances such as cyanogenic glycosides, ß-phenylethylamine, fluoroacetate and non-protein amino acids. The presence of these compounds is not necessarily limiting, but species must be selected to avoid or at least them into account.

Why is cultivation and utilisation of wattles potentially important in the wheatbelt of W.A.? The direct value of products from cultivated wattles may produce new farm income, but large-scale cultivation of the plants may also contribute to amelioration of salinisation problems. This may be accomplished with elements of the native flora and contribute to an overall increase in biodiversity. Although products of intermediate value, such as gums and tannins, would not be expected to accomplish these goals alone, in combination with bulk products such as wood pulp and fibreboard, gums, tannins and possibly resins may improve the economic picture in W.A.

INTRODUCTION

The distinctiveness of the vegetation creates the strong impression of an exotic environment in visitors new to Western Australia, a feeling that is strengthened by the unique geology, the infertility of soils and the flatness of the terrain. Although this unusual perennial sclerophyllous or 'hard-leaved' vegetation is still abundant in much of south-western W.A., it has largely been converted to agriculture based on annual plants (cereals, pasture for sheep, known locally as the 'wheat and sheep' zone). With the discovery of methods to amend the severe nutrient deficiencies of the soils during the last century this region became a rich agricultural area. However, this change has not occurred without problems.

With the flatness of the landscape and the permeability of the soils the original deep-rooted native vegetation was able to capture virtually all of the rainfall because the winter surplus was efficiently stored in the deep soils and extracted during summer. This process also efficiently accumulated the trace of salt that occurs in rainfall and, over many millennia, substantial stable storages of salt were built up. With conversion to winter-growing annual plant agriculture, the capacity for summer extraction of deeply infiltrated water was removed, groundwater accumulated and mobilised the stored salts. As rising groundwater tables intersect the surface, usually on the broad valley floors, saline water is discharged and extensive degradation of land and streams occurs. Some 10% of previously arable land has been degraded by salinity and it is projected that this will rise to more than 30% within several decades.

Many solutions to the salination problem have been proposed. One proactive approach is to replant trees and shrubs in an attempt to regenerate the original water balance. Placement of the trees in strategic locations, where surface and sub-surface down-slope water movement can be intercepted, is critical to the success of this kind of initiative. Because trees must be planted in great number to be beneficial, they must replace a significant proportion of land presently devoted to annual plant agriculture and this will reduce production. Further, the expense incurred in planting trees is significant. If such programs are to be widely adopted, these problems must be dealt with. One logical solution is for farmers to obtain financial return from the trees and shrubs themselves.

Many factors complicate the search for appropriate tree species for these planting schemes. Past experience with exotic species becoming weeds, even those from eastern Australia, suggests that widespread introduction of these plants should be avoided. Because they are adapted to local conditions, trees and shrubs native to W.A. might be expected to grow best. However, few plants native to the south-western wheat and sheep zone are productive forestry trees and, with a few exceptions such as quandong (*Santalum acuminatum*), they do not produce useful fruits, seeds, or other widely used or conventional consumer products. Obviously, the products derived must be of enough value to offset the cost of planting, maintenance, harvesting and transportation to sites where the plant materials can be processed. It seems likely that large-volume, low-cost production systems utilising all parts of tree and shrub crops and generating multiple products will be required. Because wattle species dominate in the vegetation of much of Australia (Orchard and Wilson 2001) and are especially numerous in south-western Australia, they constitute an obvious group of plants that should be considered. Although the wood of most wheatbelt wattle species is unsuitable for timber in the usual sense, it may be used to make quality panel board and paper products. In addition, these plants often contain substances of potential value, such as gums, tannins, oils (triglycerides), proteins and resins.

Gums

Of these phytochemical products, perhaps the most promising are gums. These water-soluble polysaccharides are common constituents of wattles but also are found in a number of other plants. The most important plant-derived gum exudate for its desirable properties and value is gum arabic (also commonly known as gum acacia), mostly obtained from a single African species, *Acacia senegal* (*Acacia* subgenus *Aculeiferum*). Gum arabic is produced in the Sudan by artificially wounding trees, collecting the tears of gum and transporting them to centres where they are cleaned manually to remove impurities and extraneous material, a very labour-intensive process. The gum is then dissolved, filtered, treated with charcoal, heat-treated (to reduce oxidative enzymatic activity associated with crude gum), and spray-dried (Glicksman and Sand 1973). Depending on quality, the price is between US$3.70 and US$4.30 per kilogram for spray-dried grades, and up to US$19.80 per kilogram for the best quality gums (1993 prices, Whistler and BeMiller 1993). The average yield is about 250 g/tree per year; the total annual production is approximately 60,000 tonnes (Whistler and BeMiller 1993). Substitute gums are produced by modification of starches, from bacterial cultures, from legume cultivars such as guar and carob, and from other plants, but for many applications none of these gums has the desirable physical properties of gum arabic (Whistler and BeMiller 1973, 1993).

Although the production of gums in plants is not well understood, these substances often accumulate in response to stress, injury, or bacterial, fungal or insect attack on the plant (Esau 1965). Degeneration of cells resulting in the formation of complex, variable gums occurs in a broad range of species. This process, called gummosis, results in the depletion of starch in cells and in many cases appears to involve breakdown of cell walls. Gums are usually associated with xylem cells and special structures called gum ducts (Esau 1965). Commonly they are exuded from the sites of injury into cracks and crevices in the bark or as irregular masses or 'tears' onto the surface of the trunk or branches. Gums have been collected by hand for millennia, but only in the last century have collectors purposefully injured the plants in order to collect greater amounts (Glicksman and Sand 1973).

Chemically, gums are water soluble or dispersible complex carbohydrates. Although the structures of naturally occurring plant gums vary widely, many (including the premier plant gum, gum arabic) have backbones of 1→3 linked D-galactopyranose units and most consist of four sugars: L-arabinose, L-rhamnose, D-galactose and D-glucuronic acid. Gum arabic contains the cations Mg^{++}, Ca^{++}, and K^{+} (Glicksman and Sand 1973). This substance is soluble in water to as much as 50% by weight, producing a clear, mucilaginous solution of relatively low viscosity.

Most useful properties of gums are associated with their ability to form hydrophobic or hydrophilic colloids or gels at low dry substance content (Whistler 1973). The particles in solution or suspension become hydrated and associate with each other and with other particulate matter in various products (coacervation) (Glicksman and Sand 1973). Coacervates are considered as immense interacting groups of molecules including the gums, water and other components consisting of colloids with opposite charge.

These interacting units 'thicken' mixtures and keep various components from settling out of suspension or from crystallising. When mixtures of this type are spray dried or prepared by other technologies, the gums bind to various oils, carbohydrates and proteins, stabilise and protect them from water. This 'microencapsulation' of mixture components can produce free-flowing powders of otherwise intractable and even hazardous ingredients, making them more stable, as well as easier and/or safer to utilise.

Gums are important components of many products and processes, although their presence is often not suspected by the general public. They are commonly used in prepared food products as thickeners and emulsifiers to modify physical properties of the foods and to make them conform to consumer preferences. Gums contribute to the desirable physical properties of candies, chewing gum and confections. In soft drinks they help to maintain flavourings in suspension. They are usual components of commercial ice cream where they prevent the formation of sugar and ice crystals. Gums are found in non-food applications such as cosmetics (face masks, hair cream, face powder), toothpaste and dentifrices, soap and laundry detergent, tobacco products, adhesives (paper products, postage stamps), sizes for paper and fabrics, coatings for paper products, paints (water-based paints, thixotrophic mixtures), inks (for lithography, for writing), ammunition and explosives, polishes, ceramics, oil well fracturing, water flow in fire hoses, and hot-quenched steel products. Gums are employed in a number of medical uses including emulsifiers and suspending agents for pharmaceuticals, as antiseptics, bulk laxatives, in pills and tablets, as a replacement for gelatin in capsules, for preparation of time-release capsules, and even as blood substitutes in some situations.

At present, however, the most important use of gums is for microencapsulating particles of water-sensitive, water-insoluble or hazardous materials; these include many kinds of free-flowing powders such as food mixes (puddings, cake mixes, drink mixes), flavour additives for foods, detergents, inks (for printers, 'inkless forms' and ball points), insecticides and insect repellents, herbicides and dyestuffs.

In Australia, many gums are eaten by Aborigines, including those of *A. acradenia*, *A. estrophiolata*, *A. georginae*, *A. jennerae*, *A. ligulata*, *A. murrayana*, *A. pruinocarpa*, *A. stipuligera* and *A. victoriae* (Latz, 1995). In general, however, humans are thought to be unable to digest the complex carbohydrates of gums (Whistler and BeMiller 1993).

Many wattles are capable of producing plentiful quantities of gum (Mantell 1947) and, in the past, gum from a few Australian species was collected and marketed. Among the species previously used as sources of commercial gums were *Acacia pycnantha*, *A. decurrens*, *A. dealbata*, *A. victoriae* (syn. *A. sentis*) and *A. homalophylla*, as well as the gum of an unidentified species (Glicksman and Sand 1973).

Gum from *A. rivalis* provided the basis of a small commercial industry in South Australia near Blinman in the early 1900s (Whibley and Symon 1992). However, most Australian gums were considered to be of poor quality; they dissolved poorly, were dark reddish brown, strong in taste and had a tendency to form gels rather than a mucilage with water. Aqueous solutions of wattle gums have low viscosity (Mantell 1947). Maiden (1906) noted that gums produced east of the Great Dividing Range are more or less insoluble, whereas those of the dry interior tend to be more water soluble, suggesting that gums of Western Australian wattle species may be of more interest than those examined in the past.

In more recent studies, both the physical and chemical properties of wattle gums of have been investigated by Anderson and his colleagues. The Australian species of subg. Phyllodineae examined in these studies include *A. acradenia*, *A. aestivalis*, *A. aneura*, *A. auriculiformis*, *A. bancroftiorum*, *A. calamifolia*, *A. coolgardiensis*, *A. cyclops*, *A. dealbata*, *A. dealbata* subsp. *subalpina*, *A. deanii*, *Acacia deanii* subsp. *paucijuga*, *A. decurrens*, *A. dictyophleba* (or possibly *A. melleodora*), *A. difficilis*, *A. difformis*, *A. elata*, *A. falcata*, *A. filicifolia*, *A. georginae*, *A. harpophylla*, *A. holosericea*, *A. implexa*, *A. irrorata* subsp. *irrorata*, *A. jennerae*, *A. kempeana*, *A. latescens*, *A. leptostachya*, *A. leucoclada*, *A. ligulata*, *A. longifolia*, *A. mabellae*, *A. maidenii*, *A. mearnsii*, *A. microbotrya*, *A. mangium*, *A. mollissima* (probably *A. mearnsii*), *A. montana*, *A. murrayana*, *A. parramattensis*, *A. parvipinnula*, *A. penninervis*, *A. podalyriaefolia*, *A. prainii*, *A. pruinocarpa*, *A. pubifolia*, *A. pycnantha*, *A. resinimarginea* (published as *A. microneura*), *A. retinodes*, *A. rostellifera*, *A. saliciformis*, *A. salicina*, *A. saligna* (syn. *A. cyanophylla*), *A. silvestris*, *A. stereophylla*, *A. tetragonophylla*, *A. torulosa*, *A. trachyphloia*, *A. uncinata*, *A. victoriae* and *A. xanthina* (Anderson 1972, 1978; Anderson and Dea 1969; Anderson and Gill 1975; Anderson *et al.* 1972, 1980, 1983, 1984a, b, 1985). Although initial studies indicated that gums of species of subgenus *Phyllodineae* were characterised by low rhamnose content, low acidity, low intrinsic viscosity and a high galactose/arabinose ratio, later studies revealed a much wider range of variation in many of these parameters than was initially observed (Anderson *et al.* 1984a).

Isolation of gums in the manner used in the Sudan is not economically feasible in Australia. Gum from Australian acacias will probably have to be isolated by cutting or grinding and extracting the tree material, and almost certainly will be linked to other on-going processes and products. There are many unknowns: will young plant material produce the gum or is older growth required? Is wounding required to get the plant to produce the gum? Can wounding be simulated? Can or must gum be removed in processing wood and wood fibre for making fibre or composition board? What steps are needed to clean up the gum in extracts? How much water is required? Is the gum of adequate quality when isolated in this manner?

Most likely, gum would be isolated from aqueous washes or extracts made in the manufacture of wood products. These processes require water, a commodity in limited supply in most of Australia. Although the water can be recovered, there is a significant energy cost linked to that process. Whether gum isolated in this manner will be of suitable quality is not known.

Past research suggests that the trees must be 'wounded' or 'stressed' in some way to get them to produce and accumulate sizable quantities of gum. This might be possible by selective application of herbicides. However, initial experiments with 2,4-dichlorophenol (2,4-D) (chemical defoliation) did not increase gum exudations with *A. murrayana* and a number of other species (Anderson *et al.* 1984a). Other forms of stress such as girdling trees, that would be less labor-intensive than the methods used in Africa, also may cause accumulation of gums. Extraction processes may mobilise tannins, which are found in many of the same tissues, and complicate cleaning up the gums. To determine the best methods for enhancing gum production, extraction and cleanup, studies must be carried out under Australian conditions.

The viscosity is low for gum arabic solutions compared to other commercial exudate gums, but viscosity alone doesn't determine the suitability of a gum. One must examine the physical properties and match them to particular applications. There are some properties that decrease the value of gums. Among them are insolubility, colour, strong taste and the presence of tannins. The single step of removal of tannins from wattle gums will yield gum products that then can be evaluated for various applications.

From time to time individuals or companies have advocated collection and development of Australian wattle gums as competitors for gum acacia. Most of these 'promoters' and 'entrepreneurs' have not considered either the technical aspects or the economics carefully. Gums do represent a resource that can complement other products and can offer additional income for farmers. If wattle species are cultivated, harvested and used for sources of wood products (fibre board, chip board, pulp etc.), it may be possible to isolate gums as a by-product of these processes. Most likely the trees would have to be grown under contract to companies with the financial resources to provide the processing needed and with a vital interest in obtaining gums of good quality. The developer would have to market the product for specific applications, establish that the gum really is superior for those applications and do so at competitive price.

In recent years, supplies of good quality gum arabic (from *A. senegal*) have decreased because of the long-term civil disturbance in the Sudan and because the financial rewards are insufficient for gum collectors. Consequently, many substitutes have been used and, according to Whistler and BeMiller (1993), because of irregular supply and cost, the market for plant-derived gum exudates would seem to have a limited future. Nonetheless, if these problems can be solved there is still a strong world demand for good quality gums and, if gums of the quality of gum arabic can be produced at reasonable cost from Australian wattles, this could be reversed.

Condensed tannins

The Australian species *A. mearnsii* is a major source of commercial tannins, although now production is based on plants cultivated in southern Africa and in Brazil. This species (formerly known as *A. mollissima* or *A. decurrens* var. *mollis*) was once the basis of a thriving industry that supplied colonial tanners in Victoria and N.S.W. (Searle 1991). In the late nineteenth century, wattle bark was collected widely from natural stands (Maiden 1906). By the early 1900s, plantations of *A. mearnsii* were established in Victoria (Searle 1991). This continued into the 1920s, when large quantities were extracted and leather was produced locally (Searle 1991), but then the manpower available to strip the bark from the trees decreased. Lines of *A. mearnsii* that consistently produced good quality tannins were not selected and developed. Although the bark often contained 20-40% tannin there was considerable variation in yield and quality of wild-harvested tannins. Contributing to the variability was the collection of samples from similar species such as *A. irrorata*, *A. parramatta*, and *A. decurrens.* Often the quality of the bark was low because of improper stripping and storage. Competing land uses removed a large proportion of the former tannin-producing area from consideration. There was a long wait (5-7 years) until the trees could be profitable, and the profit was often uncertain (Maiden 1906; Searle 1991). In a number of instances, plantations of wattles were attacked by insects and pathogenic rusts. Today, Australia imports tannins, mostly from China, that are produced from this Australian tree under a special joint program (Searle 1991). Although leather production in Australia has decreased in recent years, the need for tannins appears to be increasing.

Other species also have been utilised as tannin sources in the past. In South Australia *A. pycnantha*, and in Western Australia, *Eucalyptus astringens*, also were widely used as sources of condensed tannins. These species often contain 20-40% tannins in the bark (Maiden 1906).

Little is known about the identity of the proanthocyanidin molecules of condensed tannins of Australian wattle species. The only species that has been examined in any detail is *A. mearnsii*, because it represents one of the world's major tannin resources. The extract from the bark of this species contains about 70% proanthocyanidins (up to 3000 MW) (Young *et al.* 1986). The proanthocyanidins themselves consist largely of bi-, tri-, and tetrameric profisetinidins and prorobinetinidins (Roux 1972; Young *et al.* 1986; Coetzee *et al.* 1995).

Leather produced from black wattle (*A. mearnsii*) is pliable and has good colour. These tannins are used primarily for the manufacture of leather but also have applications as dyestuffs, corrosion inhibitors, to promote flow of liquids in pipes, and as pharmaceutical products. They formerly were used in the manufacture of inks. Another major demand is for production of tannin-based wood adhesives (Anonymous 2000; Searle 1991). Particle board bonded with *Acacia mearnsii* tannin adhesives has improved water resistance properties compared with urea-formaldehyde bonded board that is commonly used (Searle, 1991). Yet other uses for tannins include flocculation of clay suspensions in municipal water supplies, surface coatings for wood and thinning agents for drilling muds (Roux 1972).

As is true for gums, much basic research work must be done on tannins to ensure a quality product and to resolve problems of harvest, isolation and preparation for market. A number of species of wattle suitable for tannin production have been identified but most are native to N.S.W., Victoria and S.A. Apart from *A. pycnantha*, which is an environmental weed, none is likely to grow well in the semi-arid wheatbelt of W.A. However, preliminary tests indicate that a number of Western Australian *Acacia* species are rich in tannins. To be economically successful, these plants also would have to be useful as sources of wood products. Plants rich in tannins may not be as suitable for gum production because the presence of tannins in gums decreases the value of the latter, but this assumption should be examined in view of new separation techniques that make it possible to separate gums from tannins and to purify the gums more efficiently.

In the past, Australia was a major leather producing and exporting country; the ready availability of good quality, inexpensive tannins might put this within reach again.

Seed oils and proteins

The seeds of a number of Australian wattle species were used by Aboriginal people as sources of protein and, to a lesser extent, oils (Anonymous 2000). Among those commonly eaten in eastern Australia were *Acacia dealbata*, *A. longifolia* subsp. *sophorae*, *A. pycnantha*, *A. stenophylla* and *A. verniciflua* (Anonymous 2000). In southern Australia 42 species were eaten, but at least 47 species appear to have promise for human consumption (Maslin *et al.* 1998).

The oil content of 20 *Acacia* species, 18 of them known to have been consumed by Aborigines, was given by Brown *et al.*, (1987). These comprise mostly triglycerides (3-22%) in which either linoleic or oleic acid predominated. The protein content of *A. alata* (23.6%), *A. dealbata* (20.9%), and *A. drummondii* (28.5%) is relatively high (Rivett *et al.* 1983). Polyunsaturated oils predominate in the seeds of each of these species. In *A. cyclops* the oil from seed and funicle differs in composition–in the seed (10% dry weight of the seeds) it is highly unsaturated, whereas in the funicle (40.6%) it consists mostly of saturated fatty acids (Black 1949).

In recent years there has been a resurgence in popularity of the 'bush tucker' industry and seed from several species of wattle has been used as a source of human food (Maslin *et al.* 1998). The most important are *Acacia victoriae* and *A. murrayana*. Seed of *A. murrayana* contains as much as 5% oil and 20% protein (Maslin *et al.* 1998). The oil consists mostly of polyunsaturated fatty acids (62% linoleic acid), with 20% monounsaturated fatty acids (18% oleic acid), and 18% saturated fatty acids (Brown *et al.* 1987). The seeds of *Acacia victoriae* contain 17% protein (Brand and Cherikoff 1985).

Many wattle seeds contain proteinase inhibitors and must be heated before being consumed in order to denature these potentially toxic compounds. Others contain non-protein amino acids which can be toxic to non-adapted animals (including man) but, as these seeds have previously been eaten by humans, in these particular species the compounds occur in quantities that do not appear to be harmful (Maslin *et al.* 1998).

Cultivation and harvest of wattle seeds can provide edible oils and protein-rich press cake for both human and domestic animal consumption. There is always a good market for seed triglycerides. Fatty acids derived from these triglycerides are used commercially to make soaps, as precursors for plastics, for manufacture of lubricants, waterproofing substances, and a variety of other products. Highly unsaturated oils are traditionally used for paint and varnish formulation and are also considered highly desirable in human diets.

Terpenes

A few Australian wattles produce resins, usually mixtures of diterpenes (Forster *et al.* 1985). These lipid-soluble materials are used in a number of minor applications, primarily as adhesives that might be useful in manufacture of wood products. Some diterpenes may serve as relatively versatile precursors for synthesis of other groups of useful compounds, but *Acacia* resins will probably be only by-products with little practical value. A series of labdane diterpenes was isolated from a Western Australian species that appears to be *Acacia rossei* (Forster *et al.* 1985).

In a report of Maiden (1907), saponins were from a number of species of plants including *Acacia pulchella*, *A. anthelmintica*, *A. concinna*, *A. delibrata* and *A.* '*cunninghamii*', the last not a currently accepted name. Pedley (1999) stated that '*Acacia concurrens* together with *A. crassa, A. leiocalyx* and *A. longispicata* constitute a group of closely interrelated and taxonomically 'difficult' species belonging to the often confused and poorly defined '*A. cunninghamii* group' (see also Pedley 1974, 1978). Further, *A. anthelmintica* and *A. concinna* are non-Australian species. Recently several saponic triterpene glycosides from *Acacia victoriae* have been examined for their ability to decrease tumor cell proliferation and to induce apoptosis (Haridas *et al.* 2001; Mujoo *et al.* 2001). The distribution and chemistry of this group of compounds in wattles should be investigated more fully.

Toxicity problems

Although most compounds found in wattles are of benefit to humans and domestic livestock, there are also some harmful substances. The presence of these compounds may not rule out using a particular species, but certainly any utilisation plan must consider them. For example, many Australian plants contain fluoroacetate. This substance is apparently known from only one *Acacia* species, *A. georginae* (Georgina Gidgee), primarily of the Northern Territory (Cowan 2001). The foliage (Everist 1978) and the seeds (Latz 1995) are highly toxic to livestock and people.

Many species of Australian wattles contain cyanogenic glycosides. These substances can release hydrogen cyanide when the plants are damaged. For this to occur, both the glycosides and special enzymes, ß-glucosidases, must be present. Among Australian wattles, plants are known that lack both, that have the glycosides and not the enzymes, that have the enzymes and not the glycosides, and that have both. This last type is potentially toxic, especially to livestock. In a survey of approximately 96% of the Australian species of *Acacia*, 45 species were shown to be cyanogenic (Maslin *et al.* 1987, 1988). Forty-three of these were in subgenus *Phyllodineae* and two in subgenus *Acacia*. Cyanogenesis was limited to certain sections of the subgenus *Phyllodineae*; most cyanogenic species were in section *Juliflorae* (Maslin *et al.* 1988). The cyanogenic glycosides in subgenus *Phyllodineae* are prunasin and/or sambunigrin, derived from phenylalanine, whereas those from two species of subgenus *Acacia* are proacacipetalin, derived from leucine (Maslin *et al.* 1988). Everist (1981) noted that poisoning under field conditions was limited to *A. binervia*, *A. sparsiflora* and one species in the *A. cunninghamii* complex. As noted above, however, the *A. cunninghamii* complex is taxonomically vague and in subsequent testing the other two species were found to be non-cyanogenic (Maslin *et al.* 1987), suggesting that even these reports are dubious.

The seeds of many wattles contain non-protein amino acids. These compounds can be toxic to non-adapted animals, including man. Should the seeds be used to isolate fatty acids or triglycerides, the press cake (the residue remaining after expression of oils) of species with seeds especially rich in these compounds may have limited value for animal feed and could become a disposal problem. Of approximately 100 species of *Acacia* examined, most contained non-protein amino acids (Evans *et al.* 1977; Seneviratne and Fowden 1968). This included more than 60 species of the largely Australian subgenus *Phyllodineae* and several Australian members of subgenus *Acacia*.

Potentially toxic non-protein amino acids, such as djenkolic acid, are found in several tropical dry-zone Australian *Acacia* species, but at levels below those that normally would cause toxicity (Maslin *et al.* 1998). Because the seeds of many of these species were eaten by Aborigines, those species would appear not to contain excessive quantities of these compounds. The non-protein amino acids 2-amino-4-acetylaminobutyric acid, 2,4-diaminobutyric acid, and 2-amino-6*N*-oxalylureidopropionic acid (oxalylalbizziine) are found in the seeds of the New World species *A. angustissima* (probably from materials sometimes considered to be a distinct species, *A. boliviana*), which was introduced into Queensland for forage in the 1980s (Evans *et al.* 1985).

N-Methyltyramine characterises a number of species of *Acacia* in subgenus *Aculeiferum* section *Monacanthea*. These include species from North and South America, Africa, and Asia (Evans *et al.* 1979). The amine is found in the seeds (Evans *et al.* 1979) and in vegetative material (Evans *et al.* 1977). *N*-Methyltyramine co-occurs with ß-phenethylamine and *N*-methyl-ß-phenethylamine in vegetative material of *A. berlandieri* (Camp and Norvell 1966; Evans *et al.* 1977; Forbes *et al.* 1995). However, amines also occur in Australian species. For example, *N*,*N*-dimethyltryptamine and other *N*-methylated tryptamines have been reported from the bark of two eastern temperate zone species of subgenus *Phyllodineae*, namely, *A. maidenii* and *A. phlebophylla* (Fitzgerald and Sioumis 1965; Rovelli and Vaughan 1967).

Whether any of the above types of compounds would be of concern depends on many factors, but with careful planning and proper selection of species, otherwise toxic compounds may not be a major constraining factor in the domestication of Australian wattles. However, the chemistry of any wattles being assessed for extensive planting should be carefully investigated.

Utilisation of wattles in Western Australia?

The problems of salinisation are sufficiently serious to require immediate remediation. Cultivation of trees on former wheat lands is one of the strategies being explored for accomplishing this effect, but many problems will be encountered. Not least of these is a possible reduction in income for farmers unless suitable economic value can be found for these newly cultivated tree crops. Use of native flora will help to overcome problems that have arisen from use of introduced plants that have become invasive and weedy. Careful planting can restore a measure of the former biodiversity as well. The trees selected must be easily grown and possess a reasonable base of variation. Only those generating products such as fuels, petroleum replacements, wood products, major industrial solvents, major chemical precursors, fibres or foods are likely to be effective. To be useful, these bulk products must be of sufficient value to offset the costs of harvesting and transportation to sites where they can be processed efficiently. Nonetheless, commodities of intermediate demand and value such as gums, tannins and resins may supplement or complement low-cost bulk products. Smaller amounts of products of high value could round out this picture.

Several examples suggest that marketing chemical products from Western Australian species can be successful. One native species, sandalwood (*S. spicatum*), is cultivated, despite some challenging problems, and Australia already exports sandalwood and sandalwood oil. Another potential product, the monoterpene cineole, is isolated from several *Eucalyptus* species, notably oil mallee (*E. kochii* with two subspecies) and *E. horistes*. There are widescale plantings of these species in several places in the wheatbelt and a facility for isolation of the essential oil has been constructed.

The scheme most likely to succeed will be a mosaic of some exotic and eastern Australian plants, Western Australian natives, plants cultivated for wood products and bio-energy, with by-products based on tannins, gums and resins, wood waste for fuel, and plants used for essential oil production, all grown in combinations to suit local soil, slope and drainage, nearness to processing plants, centres of usage and shipping points, and many other factors thrown together.

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