New plant products - using Australia's genetic heritage

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Introduction

In his essay 'On the Origin of Cultivated Plants', Vavilov in 1926 sought to explain the development and diversification of agricultural plants by proposing that they had developed from 8 centres of origin (45). Though his ideas have been modified over the years and we now know that the pattern is more diffuse and complex than was originally envisaged, the complete omission of Australia from these conceptual models of plant domestication has implanted the idea that the Australian flora has nothing to offer.

It is true that the Australian Aborigines practiced virtually no agriculture, though for example their care for the plots which yielded yams has been termed 'proto agriculture'. Replanting of the shoot portion to allow reporting was widely practiced, sometimes reinforced by religious superstitions. The times of harvest were tightly controlled and in places extensive areas were harvested. Near Hutt River, Grey in 1837 (14) saw an area several miles in extent where the number of holes from yam digging made it difficult to walk across the land.

The idea that the Australian flora has little to offer was thus generated from Vavilov's concepts of centres of domestication, the lack of agricultural activity on the part of the native inhabitants and the idea that they led a miserable existence during which, despite endless toil in search of food, they were constantly on the verge of starvation and wracked by disease. This concept has been challenged by studies which suggest that at least in some areas they may have enjoyed the "original affluent society" in which both males and females tended to work for 2 days with every 3rd day a holiday (38). As to why the Aborigines did not initiate agricultural activity we have this telling reply (3)

You people go to all that trouble, working and planting seeds, but we do not have to do that. All these things are there for us, the Ancestral Beings left them for us. In the end, you depend on the sun and the rain just the same as we do, but the difference is that we just have to go and collect the food when it is ripe. We do not have all this other trouble.

It is interesting to find that a large number of the food plants used by the Aborigines are members of genera for which domestication has been successful elsewhere in the world (15). Thus there is potential for utilizing Australian species for improvement of cultivars developed overseas, and this applies not only to genera of food plants (Table 1), but also to those used for floriculture, industrial products or fodder. Genera that have been used in this way include Nicotiana, Glycine and Gossypium (29). Our knowledge of the genetic relationships between the Australian species and the cultivars needs to be investigated before we can assess the level of contribution that the Australian genomes might make.

It is estimated that there are some 25,000 species of seed plants in Australia. The tide of opinion is swinging towards the possibility for direct use of some of these plants rather than just as contributors of genes to plants domesticated elsewhere. This opinion has been catalysed by popular programmes such as the TV series 'The Bush Tucker Man' newspaper articles and the publication of several recent books on bush food (18,26) and medicine (9).

Table 1. Some genera that include one or more species harvested for food by Australian Aborigines(15)

Acacia	Dolichos	Lucuma	Rubus
Adansonia	Elaeagnus	Luffa	Rumex
Aleurites	Eleocharis	Macadamia	Sambucus
Alocasia	Eleusine	Marsilea	Sesbania
Amaranthus	Eragrostis	Mucuna	Solanum
Amorphophallus	Eriochloa	Musa	Sorghum
Araucaria	Eucalyptus	Nasturtium	Sporobolus
Boerhoavia	Eugenia	Nelumbo	Tacca
Bowenia	Ficus	Nymphaea	Terminalia
Calamus	Gastrodia	Ocimum	Trigonella
Canavalia	Geranium	Oryza	Typha
Capparis	Grewia	Oxalis	Vigna
Chenopodium	Haemodorum	Pandanus	Vitex
Citrus	Hibiscus	Panicum	Vitis
Cucumis	Ipomoea	Physalis	Zamia
Cyperus	Lagenaria	Piper	Zizyphus
Dactyloctenium	Lepidium	Podocarpus	
Digitaria	Linum	Polygonum	
Dioscorea	Loranthus	Portulaca	

This paper will look at the reasons why the time is now ripe to more fully explore the Australian flora for species worth domesticating, the range of products possible, the time frame and cost of developing new products, and the problem of protecting our 'genetic heritage'.

Incentives for research and development

With the increasing world population it might be argued that additional and alternative food sources are required. This is not a strong argument as food distribution rather than food production needs to be improved, and if we were really serious about producing more food we could do so immediately by stopping producing non-essential crops such as tobacco, coffee, tea, and cut flowers (16) or investigating leaf protein more thoroughly. However, in affluent societies there is a move to a more vegetarian diet, and pressure to provide new foods and flavours.

In Australia there is a desire to develop an Australian culinary identity, as much for the benefit of tourists as for the locals. It would be ironic if the food of the Aborigines, who could be described as people who "eat to live", becomes the food of the foodies who "live to eat". However, some of the potential new food products are able to grow in the rangelands controlled by Aborigines. We have therefore the possibility of improving the nutrition of these people by encouraging the cultivation of traditional foods and adding to the income of communities by sale of cultivated and bush-collected foods. Another market pull is towards natural, rather than synthetic colours and flavours (even if, as scientists we may sometimes think that this consumer preference is irrational). There is also a growing demand for other 'natural' products such as insecticides or drugs.

A second reason to believe that it is timely to invest in domestication of native plants is the deterioration of the environment even without the superimposed predicted effects of the CO_2 increase and the damage to the ozone layer. The problem of supplying water to Australian cities means that greater use should be made of arid-zone species in the landscaping of domestic and public amenities. The destruction of forests through acid rain or indiscriminate logging means that fast-growing Australian species have a role to play in plantation forestry.

Thirdly the small share that Australia presently holds in the world market for floricultural products (0.06%) and the importance of novelty in this market means that there is great potential for development of new floricultural products. With our current knowledge of breeding through selection and hybridization, manipulation of the genome, propagation through conventional and in vitro methods, we are surely in a good position to capitalize on the opportunities available.

Areas of genetic resources

Food

It is in the area of food that a lot of publicity has recently been focussed. Bush foods are already in use (32). In Sydney Rowntrees restaurant has a 'theme' of bush food and Qantas has featured wattle seed ice-cream and lamb with the plum from Podocarpus elatus. Other companies such as Kurri-Kurri Foods produce jams and chutneys, and bush food has been used as a promotional feature overseas for tour advertisements or sale of Aboriginal art. Those who promote use of bush food are keen to secure regular sources of supply and to avoid devastating bush harvesting.

Where might success be most quickly found?

I suggest that nuts or other hard woody fruits that transport and store well might be easiest to develop and market. The only domesticated Australian food plant, the Macadamia (M. integrifolia and M. tetraphylla), gives encouragement even though it must be remembered that present success with Macadamia is related to the fact that it has been in cultivation now for almost 100 years, having been planted in Hawaii about 1892. Other species of Proteaceae with potentially good nuts are Athertonia diversifolia said to have an excellent flavour similar to Macadamia; Hicksbeachia (ivory silky oak or monkey nut) and for drier areas Grevillea annalifera which has small seeds similar to almonds in texture and taste. The seeds of many other species of Proteaceae are disappointing often being bitter because of cyanide or insipid to taste. It is impossible to know if cyanide-free mutants of species at present unpalatable would be tasty although investigations of Macadamia whelanii and M. praealta which have very large exceptionally bitter nuts up to 5 cm in diameter would seem worthwhile (18,22). From other families, species with potential include Sterculia quadrifida (bush peanuts) and Araucaria bidwillii (bunya pine). Other species from which toxic compounds would have to be removed during domestication are the bush cashew (Semecarpus australiensis), the kurrajong and sandalwood. The difficulty of extracting Pandanos seeds makes it unlikely that these would ever be domesticated even though they were highly regarded by Aborigines (18).

The advantages that nut crops have in keeping and transport qualities, low bird predation, and the possibility of use in agro forestry, are somewhat outweighed by difficulties of harvesting, and the long generation time in any improvement programme.

Many native fruits have common names like quince, plum, cherry, peach and so on, but with the exception of figs (Ficus) and raspberry (Rubus) they have no botanical relationship to their exotic namesakes and only the faintest resemblance in appearance or taste. Some of the soft fruits of the Australian bush are only edible when overripe, and this makes them difficult to market except for eating directly off the bush. Many have a degree of bitterness, sourness and fibre that is not acceptable and would require a long period of breeding to improvement. There is a world of difference between 'edible' and 'saleable'. Despite this, a fleshy fruit will soon be released. Peter Hardwick of Wilderness Foods in Byron Bay NSW is releasing a selection of Carpobrotus called Noolli (which certainly sounds more attractive than pigface), which has been selected for for juicy fruits with a long stem to enable harvesting. It is said to taste like a cross between a strawberry and a kiwifruit, bears 8-12 months after planting and is drought and salt tolerant (32). A company run by Vic Cherikoff called North Australian Resources has started plantations of billy goat plum Terminalia ferdinandiana, a rich source of vitamin C.

The Quantong is a species into which CSIRO's Division of Horticulture has put considerable effort for improvement of the flesh (34,39). Initially the kernel too was being developed as an alternative product, but methyl benzoate can give some nuts a most objectionable after-taste and questions about the safety of consumption of some of the unusual fatty acids (e.g. santalbic acid) in the oil of the endosperm has made development of the nut doubtful (Dr G. Jones, Deakin, pers comm.)

Analysis of native foods has shown many to have high nutritive value (5), but it is likely that in 'improving' the fruits and seeds food value may change. For example, when cereals are selected for increased seed size this is usually as a result of increased endosperm and therefore accompanied by a fall in relative

protein content. Similarly improvement of sweetness of native fruits may well lead to a drop in overall nutritive value.

The problem of the toxic properties of many bush foods, and the understandable reluctance of the modern consumer to spend days leaching, baking and otherwise detoxifying products leads me to the point that when introducing a new food one must be certain that it contains only low, or no, toxic or carcinogenic compounds. Interestingly, both in Australia and America (21) the guidelines for the introduction of new food additives appear more rigorous (involving a requirement for toxicological and pharmacological testing) than those for the introduction of a new food plant. The fact that the plant has been commonly used in diets is helpful. Rightly or wrongly, use in traditional Aboriginal diets is probably not given as much weight as use in western diets. However, the distinction between a food and a food additive is blurred. Terminalia plums are a food; these plums in a chutney are a food additive. One approved food additive derived from the Australian flora is 13-carotene from the alga Dunaliella salina. The salt lakes of Australia have provided the selection screen for high yielding lines that are now grown commercially by two companies and provide exports worth over $2 million each year (4).

To be legally safe in introducing a new food, one must first ensure that it is produced and handled under hygienic conditions (bush collected food might be a little suspect in this regard) and then apply to the National Health and Medical Research Council for assessment of the new food. An instructive example of a new crop being re-introduced into Western diets is the Sweet White Lupin. The Western Australian Health Food Standards Regulations state that lupin flour shall not contain more than 200 mg/kg of alkaloids, but in order to satisfy overseas trading partners that John Gladstones cultivars are so low in alkaloids that they are safe for human consumption, the Grain Pool arranged for samples to be examined by an internationally-recognized toxicological body - the British Industrial Biological Research Organization. Following WHO criteria, tests were carried out, such as 90 day feeding trials with rats and AMES tests with Salmonella for mutagenesis (Michael Jackson, Health Dept. W.A. pers. comm.). For an important crop like lupins the 50,000 pounds sterling needed for this testing was a good investment; it is doubtful that producers would be able to afford such expense for minor food crops.

Another method which gives some slight legal protection is to warn the consumer of possible danger. However, while we have more and more stringent regulations about food additives, e.g. the level of erratic acid in rapeseed oil, the level of tyrosine inhibitor in soybean meal, etc. it is unlikely that we will be able to introduce *new* food plants with little restriction.

Drugs

It is in this area that success is most problematical. The odds against a new active compound becoming a drug that meets present-day standards are about 3000 to 1 (13). Drug companies need considerable resources to be able to carry out the exhaustive investigations of mutagenicity, teratogenicity, animal toxicology and clinical studies associated with promising compounds. The compounds have to be shown to be both safe and effective. The initial research costs may be a surprisingly small part of the total cost. A recent estimate of the timing and cost of bringing a new product to the initial sales stage showed three years of development and testing ($13.3 million) followed by nine years of organization of sales and market start up ($12.0M) and manufacturing start up ($30.0M) (44). The cost of introducing a new compound for veterinary use, for the health food market, or as a non-prescription medicine is rather less, but still considerable. Researchers who have identified promising compounds from the Australian flora may therefore experience great difficulty interesting pharmaceutical companies in developing their results further. This has been found by Dr Gwyn Jones of Deakin University, who discovered that the quandong kernels used by Aborigines to treat scalp wounds have active compounds, but that support for further research on the medicinal properties has been hard to gain.

Between 1974 and 1981 a Swiss Company, Roche, surveyed the marine algal flora of Australia and found a large number of active compounds of therapeutic value. In this case the research has not yet been followed through because the company withdrew support when it had to restructure due to a totally unrelated problem - Valium (2,35).

When the flora is surveyed for new drugs the intention is, wherever possible, to chemically synthesize the compounds discovered rather than to set up plantations and have supply subject to the vagaries of climate, pests and political change. Thus the agricultural and horticultural industries may not benefit even if an AIDS where were found in Australian plants (American scientists at Beltsville and Bethesda are strongly interested in Castanospermum for this purpose). Only 25% of drugs used in America are of natural plant origin.

That there are useful drugs in Australian plants no-one doubts. There are species known to have antibiotic properties, to control dysentery or to contain useful alkaloids and contraceptives (18). It is interesting that species common to Arnhem Land and the Indo-Malaysian region are very frequently (89% of species) put to the same medicinal use by indigenous peoples.

The Australian drug plants that are harvested commercially yield compounds that are the same or similar to those already accepted in medicine. They do not produce compounds unique to the Australian flora. Examples are Duboisia leichhardtii and D. myoporoides whose leaves yield scopolamine, hyoscyamine and other alkaloids; E. macrorhyncha which yields rutin, (a product which may not survive competition with the Chinese product from Sophora japanica); and Solanum aviculare and S. laciniatum, which are widely planted in Russia for steroids and are probably the only Australian plants to appear on a Russian postage stamp (9).

One interesting apparent omission in the range of bush products is effective insecticides. The Aborigines appear to have used smoke as a deterrent against flies in wounds, and have not used plant substances to avoid pestering by flies or other body parasites. This is in contrast to natives of Africa and Central America (31). Perhaps the use of plants for insecticides develops along with agriculture and the need to control pests on cultivated plants, domestic animals and in stored food.

Forage

The highly salt-tolerant perennial shrubs in the genus Rhagodia, Maireana and Atriplex are recognized as valuable fodder with good palatability and high protein content (47), and exceptional tolerance to dry and saline conditions. The South Africans have developed a cultivar of oldman saltbush A. nummularia (cv de Koek) which has been re-introduced into Australia and is popular around Dubbo. Research in Western Australia by Clive Malcolm, however, indicates that selections of A. amnicola from the Gascoyne and Murchison River basin region have even more potential. Two cultivars have been developed, Meeberry and Rivermore.

In the book 'Under-Exploited Tropical Plants with Promising Economic Value'(33) another Australian species is included. Cassia sturtii has been found to have potential as a fodder shrub in the Negev in Israel, yet it is rarely grazed by cattle or sheep in Australia. One wonders whether there are hidden long-term problems with this species, or perhaps if the animals have a different rumen flora enabling them to utilize this species in Israel but not in Australia.

Seaweeds and seagrasses

The marine flora is often neglected when considering our genetic resources. Reference has already been made to the commercial use of the salt lake alga Dunaliella, and the survey of marine algae for drugs. The Aborigines made little use of algae occasionally eating brown or green algae and using fibre from sea grasses. Other cultures, particularly in Asia, make extensive use of seaweeds as sources of food, medicine, animal fodder and agricultural fertilizer. In Australia at present there is only a cottage industry on King Island in Bass Strait where the bull kelp Durvillea cast up on the beach is harvested for alginate. Trawling for seaweeds is very costly but seaweed farming using mesh and rafts is common in Asia. An Esperance company, Australian Underwater Research and Development Investigations, is establishing feasibility trials of 'farms' of Gracilaria for agar production at Albany. Another technique that may be even more valuable is growing macro seaweeds on land on shelves provided with a fine mist of seawater. Annual yields of up to 140 dry tons per hectare have been recorded (27). The seagrasses occasionally elicit interest for harvest of the durable fibres in their leaf bases, both preserved in the sediment and from

living stands. During the war the possibility of harvesting Posidonia from South Australia was investigated, but it was decided that the resource base was too small for continued commercial viability. Today the environmental degradation that would result from destruction of the seagrass beds would be unacceptable.

With predicted changes in sea temperature and sea levels, long-term investment in mariculture may be risky.

Plants for floriculture, ornamental horticulture and turf

The high potential of many native species for the floriculture and nursery industry is shown by the diversity of species and volume of material bush-harvested (7,36,37), and the increasing enthusiasm for cultivating native species as described in several books (12,23,46) and a recent conference 'The Production and Marketing of Australian Flora', conducted by the Western Australian Department of Agriculture. The size of the world market in cut flowers (around US$25,000 million), the need for novelty in the market, and the range of beautiful species in our flora leaves no doubt that many Australian species could repay cultivation. John Considine's recent paper at ANZAAS(8) described the criteria which must be applied to the abundance of available material so as to select those most likely to succeed in the world market (Table 2).

Table 2. Criteria to use to select plants from the Australian flora most likely to be successful as cut flowers or pot plants(8)

Soft
Small
Low Scent
Attractive
Long lasting
Cold tolerant
Disease tolerant
Low allergenicity
Variety of colour forms
Herbaceous or small shrub
Controllable flowering season
Simple agronomic requirements

It is in the area of floriculture in kangaroo paws that we have a good example of a successful recent domestication. In Western Australia, Steven Hopper and Keith Oliver investigated the range of form in the various species of Anigozanthos and the hybridization possible. This was complemented by breeding work in the Eastern States by Mery Turner and at the University of Sydney. The discovery that fast mass propagation of superior clones was possible launched the product. The in vitro work was done by Ellyard at the Canberra Botanic Gardens, and Stuart Newton and myself at Murdoch. Phil Watkins and Linda Penny at the Western Australian Department of Agriculture and Peter Goodwin in Sydney then did research on the cultivation practices for these plants. Work has also been done on disease resistance by Dr Sivasithamparam at the University of Western Australia and by the Western Australian Department of Agriculture on market research and post-harvest physiology. Research by private companies such as Plantex (Aust) and Biotech Plants has led to the release of new cultivars better adapted as cut flowers (e.g. cvs Big Red, Big Yellow and Harmony) or to pot- plant production (e.g. cv Mini pearl, the Bush Gems range and the Bicentennial Kangaroo Paw) and refinement of the in vitro propagation methods. This example shows the level of input that is necessary both for the breeding and commercial cultivation of a new product and the benefit of open access to research results. In developing other species or groups of species even more effort may be necessary -kangaroo paws domesticated relatively easily.

Many other Australian species are being investigated for use as foliage plants for interior decorating and some grasses are being investigated which may reduce the necessity for mowing (Danthonia and Pennisetum), or which are tolerant to brackish-saline irrigation water (Distichlis distichophylla).

Wood and paper pulp

The development of so-called paper-less office systems has not reduced the demand for paper pulp. It is estimated that by 1997 the demand for pulp in Japan will have doubled to 5.5 million cubic meters per annum. The requirement for firewood too is important, being particularly high in developing countries. In SE Asia many countries have already cleared more than 50% of their forested areas(1) and you are all aware of the environmental damage and social conflict being caused by logging. In response to this Thailand has curtailed all harvesting from native forests, and is encouraging other countries to do the same. Many countries are setting up plantations of both native and exotic species. Australia was one of the later countries to start eucalypt plantations (17,48) with the result that we are only now beginning to have available superior selections from the first harvesting cycles. Experience overseas indicates that cloning superior trees can dramatically improve yield and reduce the harvest cutting cycle time but it must be complimented by conventional breeding to ensure the long-term improvement of plantations (25,30).

At Murdoch we have been part of a team effort involving CSIRO, UWA, Plantex (Australia) and PPM, with Alcoa as co-ordinator, to select and clone superior pulp trees (Eucalyptus globulus and E. nitens) and trees resistant to saline waterlogging (Eucalyptus, Acacia, Melaleuca and Casuarina species) and mycorrhizal fungi appropriate to these species (19). This research has indicated the feasibility of utilizing our genetic resources in this way and we are now at the stage of putting **in** field trials in Australia and overseas and surveying the export market possibilities with aid from an Innovative Agricultural Marketing Programme grant. The Western Australian CALM/Hardwood Share-farming Scheme to plant at least 100,000 hectares over 10 years with E. globulus offers local farmers an opportunity to invest in pulp production and at the same time help control the salination of our water supplies (40). The salt tolerant species that we have selected will have the effect of reducing salt encroachment and could provide valued firewood from wasteland in developing countries.

One worrying feature is the development of an anti-eucalypt lobby apparently originating in the Indian state of Karnataka in the early 80s and being propagated by journalists and environmentalists. The thrust of their argument is that eucalypts increase water runoff, prevent undergrowth, do not enrich the soil, consume water copiously, lower the water table and poison the soil; in short that eucalypts do nothing but environmental harm. Unfortunately papers disproving the claims and showing how species might be selected depending on whether or not one wants to lower the water table (e.g. 10,11) have not been given as much exposure as papers promoting the bad image.

Tannin

Annual world production of tannin is at present around 350,000 tons. A large proportion comes from South Africa where the Australian species Acacia mearnsii (black wattle) has been grown in plantations since 1884. The product is used not only for tanning hides, but extensively for adhesives and resins. However, it is likely that even if political instability in South Africa led to a breakdown in supply, Australia would not be able to compete to fill the market as other countries with cheap labour such as India and Thailand are already establishing plantations of this Australian species.

Eucalyptus oil

It is surprising that Australia is a net importer of Eucalyptus oil, exporting high cineole oils, but importing industrial grade oils, mostly from Spain and Portugal. Some of the oil is re-exported after blending with the local product (24). Eucalyptus oil was perhaps Australia's first industrial product, a sample from E. piperita being shipped from Port Jackson in 1788. Current production is largely from E. polybractea in natural stands. Research at Murdoch by Alan Barton has examined within and between species variation in oil content and composition of a large number of West Australian species. Promising species that are good or better than E. polybractea include E. kochii subsp. kochii and plenissima (6) and seedlings from

selected trees have been planted in field trials at the Wongan Hills Department of Agriculture and on private land. At present the establishment of plantations solely for the purpose of producing oil cannot be justified financially (41) and experience elsewhere shows that a combination of harvest for wood and oil from the same plantation is rarely successful. Thus although E. globulus is the basis of the South African oil industry it is unlikely that we can combine the CALM E. globulus plantations for pulp with harvest of oil from leaves. However, planting of high-oil eucalypts in catchment areas for salinity control may be a viable option. Certainly there is world-wide interest in the product as some 25 patent applications are filed each year involving eucalyptus oil or cineole. Australia should be able to gain more than 10% of the annual $20 million market for cineole for the pharmaceutical industry.

Other essential oils

The Melaleuca oil industry has the potential to develop into a $20-25 million industry within 8-10 years (42). Teaco International of Santa Barbara California report that their monthly sales have risen from below $1,000 per month in 1987 to over $100,000 per month. Based mainly on M. alternifolia, the industry is at a transition stage from harvesting from natural stands to plantation production. Apart from its well-known bacteriocidal activity, the oil is used as a perfumery toner and nutmeg substitute (42).

The beautifully-perfumed Western Australian Boronia megastigma is collected from the wild, but it is possible that harvesting from the wild will be phased out. Plantations have been established in Victoria and Tasmania, and more recently in Western Australia. The oil is used in cosmetics and as a food additive to give fruit-type flavours. The University of Tasmania together with their state government and private enterprise has set up a company 'Essential Oils of Tasmania' which is conducting a programme of research and development for crops including Boronia, for which they have developed several cultivars with desirable plant architecture for mechanical harvesting, and with different oil characteristics for perfumery (20). B. purdieana and Olearia are also being investigated and numerous species hold promise (28). However, it may be necessary for growers to combine resources to carry out the necessary scientific and market research and the advertising. The cost of flower production from plantations has to be lowered to make sale of flowers for oil economic, and further use of the oil as a food additive promoted, as "Essential Oils of Tasmania" claim that they will be filling 95% of the world market requirement for perfume oil by 1990. Growers in Western Australia have not yet decided whether the long term future of their plantations is for oil or cutflowers.

Hydrocarbons

Numerous Australian species contain appreciable levels of 'hydrocarbons' or 'resins' and every time there is an oil crisis interest in these species rises, particularly if one is looking for plants capable of growing in the more arid areas where their development would not compete with more conventional agricultural crops. Data are limited, but it appears that exotic species such as guayule (Parthenium argentatum) offer more potential than any Australian species, and that if agricultural land can be used, oil seed crops are more competitive economically (43).

Protection of Australia's Plant Genetic Resources

Australia's gift to the world?

Agricultural production in Australia is at present almost completely dependent on exotic plants and animals domesticated elsewhere. It has been traditional for Australia to export seeds or plants of Australian material freely for scientific research, for aid to overseas countries or as gifts to cement sister city relationships (e.g. Brachycome multifida from Western Australia to Hyogo Prefecture in Japan). It is difficult to quantify the flow as it comes from seed export companies, botanic gardens and herbaria, agriculture and forestry departments, CSIRO, and Universities. For example, the CSIRO Seed Centre despatches some 14,000 seedlots p.a., 55% to overseas countries. Opportunities have been lost in the past through lack of vision (Macadamia to Hawaii, Solanum to Russia, Waratah to New Zealand) or lack of cheap labour (A. mearnsii to S. Africa, and Eucalyptus to various countries). For some of the products being developed now in floriculture and forestry, parallel development of these industries overseas may

complement activity in Australia by making products available over a longer time period or in greater volume than we are able to provide.

Thus, I would suggest that a ban on export of genetic material is unlikely to be universally popular and impossible to enforce. Exchange of material for the purpose of basic research will always be necessary and the distinction between basic, applied and commercial research are becoming more and more indistinct. The alternative strategy of a vigorous programme of research and development that provides leadership in commercialization and ensures a continuous flow of new improved material on to the market is one line of defence.

Plant variety rights

The introduction of Plant Variety Rights gives another line of defence, as it has provided incentive for breeders to develop cultivars of Australian plants and will result in new lines being placed on the market in an orderly way, with potential users being given adequate data to assess the qualities of the new lines compared with older related varieties. The initial legislation had a severe drawback for breeders associated with horticulture, forestry and ornamental plants, in that asexual propagation of registered varieties was not prohibited if the product of the plants (fruit or flowers) were sold and not the plants themselves. It is likely that the legislation will be modified to give the breeder control over asexual propagation (Plant Varieties Journal 2 (1)), while not precluding farmers from keeping seed for the next year's crop. Plant Variety Rights cannot, of course, be given to collections taken from the bush, some deliberate breeding must have been imposed. The timetable for inclusion of genera of Australian native species means that some are already covered and that all should be covered by mid 1990 (Table 3).

Table 3. Proposed Timetable for Inclusion of Genera in Plant Variety Rights Regulations. Plant Varieties Journal 2(1) 1989

April 1988	July 1988	January 1989	July 1989	March 1990
Anigozanthos	Artanema	Acacia	All fruits,	All native
Macadamia	Chamelaucium	Callistemon	nuts and	ornamentals
	Decaspermum	Casuarina	herbage	
	Eucalyptus	Duboisia	Banksia	
	Grevillea	Dryandra	Boronia	
	Lechenaultia	Macropidia	Carpobrotus	
	Melaleuca	Piper	Darwinia	
	Orchids	Telopea	Pimelea	
	(all genera)	Thryptomene	Verticordia	

It is appropriate that in February 1989 the first Australian Plant Variety Rights were granted to H., M. and D. Bell for two varieties selected from seedlings of a hybrid Macadamia integrifolia x tetraphylla (Varieties Hidden Valley A4 and A16). Applications accepted but not yet finalized include a kangaroo paw selected from seedlings possibly from Aniaozanthos bicolor and A. humilis (variety Firefly), and three varieties of Lechenaultia; the imaginatively named L. formosa variety Fantail Flamingo and Fantail Starburst, and a L. formosa x L. biloba hybrid Fantail Ultraviolet, all bred by G. Lamont of the NSW Department of Agriculture (Plant Varieties Journal 1 (2), 1 (4)). I look forward to the day that Australian breeders patent a cultivar of a New Zealand species, to retaliate for the New Zealanders patenting Waratah as Kiwi Rose.

There are still some problems to be solved with Plant Varieties Rights. It is difficult to register a dioecious variable strain such as Atriplex as it is hard to define it morphologically, even though it may have some highly desirable characteristics such as salt tolerance or ability to volunteer from seed. There is also a problem with forest tree clones where a large number of clones should be included to keep up the diversity of the long-lived species. The plants are devoid of morphological markers and will need to be described on the basis of laboratory techniques. Isozymes have been used to help define varieties but as

yet no variety has been approved on the basis of DNA fingerprinting. Further, it will be unnecessarily cumbersome to register each of perhaps 50 clonal lines which may be required for clonal diversity; the group of clones will have to be registered together.

Summary

Only a small proportion of the 25,000 species in the Australian flora are being utilized commercially, and some of these are more highly utilized outside Australia. The recent media exposure of Aboriginal foodstuffs and medicines has given rise to somewhat unrealistic expectations of riches to come from the introduction of such native products. These expectations have to be tempered with the realization of the problems of regulation by the NHMRC on food and food additives and the high costs for introduction of a new drug.

The genetic resources in the Australian flora will most easily be turned to profit from use of native plants in floriculture, ornamental horticulture, forestry, forage and essential oils.

Reference

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