Developments - new kinds of plants

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Introduction

I wish consider the development of new kinds of plants for Australian agriculture in the context of the theme of conference 'Looking back and planning ahead'. For the purposes of this paper the term, a new kind of plant, will be taken to mean a cultivated species or genotype that has a set of economically important attributes different from existing ones. Such new crops or plants can be grouped into three classes:

- partially domesticated, under-exploited, or wild species brought into cultivation in advanced agricultural systems;
- established crops or pasture plants imported from abroad;
- new cultivars, especially those allowing the development of new products or markets, of already established crops developed by conventional breeding and/or genetic engineering and other new biotechnologies.

It should be emphasised that this subdivision is arbitrary and some speciesmay fall into more than one category, depending on the way they are viewed. For example, *Lupinus angustifolius* now Australia's most widely grown grain legume crop following the innovative research of Dr John Gladstones can be regarded as a semi-domesticated species that is now fully domesticated (group 1), or an already cultivated plant for which new genotypes were developed to meet new needs (group 3). Nevertheless, this subdivision provides a useful framework in which to consider new types of plants and I consider each group in turn below.

Partial domesticates or wild plants

A retrospective assessment indicates that Australian breeders have made a substantial contribution to the domestication of two main groups of plant species. These are (i) temperate and tropical pasture plants (such as *Trifolium subterraneum,* annual *Medicago* species and annual and perennial *Stylosanthes* species (for example (1)), and (ii) Australian native plants for use in floriculture, amenity horticulture and forestry. With the notable exception of Dr John Gladstone's role in the development of lupins as a viable grain legume crop, our contribution to the successful domestication of new field crops has been limited.

There is still considerable interest and effort in Australia in the identification and commercialisation of new pasture plants. However, the level of activity is substantially less than during the 1950s and early 1960s. As a consequence, such programmes have become more focussed and the emphasis has shifted from simply a search for more productive species to those that would improve the sustainability, both ecological and economic, of Australian agriculture. The latter include species of value in reducing or preferably reversing rising soil acidity, deep-rooted long-lived perennials of value in maintaining water-tables at non-damaging levels, and species that can better persist under the high and continuous grazing pressures that are required if farmers are to survive at current commodity prices. There is also an increasing interest in the commercialisation of a number of indigenous Australian grasses *(Danthonia* and *Astragla* spp.) and legumes (e.g., *Glycine* sp.) as pasture species for use in the rehabilitation of marginal lands, low-cost pastures and minimal input parklands and other amenity areas.

The development of new crop plants from partially domesticated or wild species, on the other hand, is a much debated and highly controversial issue.

<u>Exotic species.</u> In the case of exotic crop species, this debate has been between those who see great potential for new crops and those that see great problems in their development. Those that see great opportunities in domesticating wild species argue (i) that there are vast plant resources on this planet

which include 3000 tropical fruits, 10,000 grasses, 18,000 legumes and 60,000 medicinal plants (6) and (ii) we have chosen to exploit only a tiny percentage of the known useful species and (iii) those that were chosen for exploitation were selected by our forebears who had little knowledge of genetics, chemistry, nutrition and limited access to germplasm. Based on such arguments it is suggested that, with today's powerful and sophisticated technologies, we should be able to significantly broaden the range and diversity of our cultivated plants and build a more reliable resource base for the human population (5,6).

Those favouring the alternative pessimistic viewpoint acknowledge the great diversity that exists within and between the 350,000 plus species of higher plants that occur around the world. However, they emphasise that throughout history, man has used only about 3,000 plant species for food. Of these, some 350 species were grown widely enough to enter world trade. Of these only 15 crops feed the bulk of the world's population and of these only four (wheat, rice, maize and potatoes) account for about half of the total weight of plant food produced. Over the last few decades the range of crops on which we rely has generally narrowed and we have become increasingly dependent on fewer highly adaptable productive crops. They suggest that against this background of increasing specialisation in readily saleable and highly productive crops, the opportunities for new crops is limited.

In the final analysis, the ultimate factor determining the fate of a new crop is economics: whether the benefits exceed the costs. In most cases it must be said that the costs are high and the benefits are often limited in the short term. For example, Table 1 lists a series of potential new crops which have been the subject of substantial R&D programs in the US in recent years. The point is that only two species, jojoba and kenaf, are being grown commercially and then only after long-term (15 to 30 years) and expensive (several million dollars) R&D programmes involving government agencies, producers and end-users.

Nevertheless, despite these difficulties, there are some new species showing promise in Australia including guayule (4) and several wild *Lupinus* species.

Australian native species. In the case of Australian native species, the debate has focussed on the involvement, or more pointedly lack of involvement, of Australian scientists and entrepreneurs in domesticating Australian plants. Native species have been widely used overseas and often domesticated in other countries. For example, it is estimated that Australian species represent 60% of tropical forestry plantings. The success of overseas countries in exploiting our indigenous species has led to the argument that Australians are frittering away their national heritage and that we have been unimaginative and backward in our effort to commercialise what we inherited. There is a strong chauvinistic movement to increase the commercial exploitation of Australia's genetic heritage by Australians. It is now often suggested, to help this process, that there should be a ban on the export of reproductive material of our native flora from this country. The idea is that this would prevent others from exploiting these plants until we were better able to commercialise them.

However, there are good biological and economic reasons why Australian native species have been exploited offshore. It is the same reason that our own agriculture is dependent almost entirely on exotic plants and animals. It is also the same reason that most countries, including many developing countries, each with a rich native flora, are very heavily dependent on introduced crops (7). The reason is that most crops in their country of origin are afflicted with a suite of coevolved and highly adapted pests and diseases which increasingly cause severe economic problems if a species is commercialised in its country of origin. The same species exported overseas without their coevolved pests and diseases, perform better and are economically more attractive. For example, eucalypts do not necessarily achieve the same growth rates in Australia as they do in Brazil, Mexico or South Africa.

In the light of this point it would be foolish indeed to bar the export of reproductive material of Australian native species. We would be jeopardizing our current and future exports of agricultural products worth of $20 billion/year based almost entirely on germplasm that others have given us free of charge, in the hope that we could develop local industries based on native plants to replace them. This is not good biology, wise politics, or sound economics.

Exotic domesticates

Looking back it is clear that our record in importing and adapting crop and pasture plants domesticated overseas into Australia has been outstanding. All of our crop plants, all of our fruits and vegetables, and the great majority of our improved pasture plants are exotic domesticates.

Up until the 1950s and 1960s a number of government institutions such as CSIRO, the State Departments of Agriculture, and some universities had strong plant introduction programmes seeking new species for Australian agriculture. However, in recent decades such programmes have received less emphasis and support, in part, because there was a perceived lack of need and in part, because there was greater emphasis given to studying and exploiting our native Australian flora. This does not mean that there was less plant material imported into Australia. Rather the emphasis changed from importing potential new crops to importing germplasm to improve existing crops.

Despite the overall decline in resources going into the research for new exotics, rural crisis caused by low prices for our traditional agricultural commodities, push by the government for increased exports, or each wave of new immigrants from another region of the world leads to a burst of activity in this area. At the present time, the search for overseas domesticates with potential in Australia is concentrated on four groups of species:

<u>Tropical/sub-tropical horticultural species with export potential to Asia.</u> Asia is perceived to offer large and growing markets for fresh fruits and vegetables. As a consequence, programmes have been initiated to evaluate a range of tropical and sub-tropical fruits and vegetables in demand in Asia for their production potential in Australia.

<u>Alternative crops to cereals in the drier margins of Australia wheat belt.</u> Farmers in the drier margins of the Australian wheat belt, particularly those on alkaline soils, remain limited in their choice of crop rotations. Traditionally they have grown cereals in rotation with medic based annual pastures. However, this system no longer is profitable for many farmers. Some of the alternatives under active investigation are *Brassica juncea, Vicia narbonensis* and a range of other annual *Vicia* and *Lathyrus* species which can either be grown for grain or with oats or hay.

<u>Minor cops for import replacement and export.</u> A range of minor crops are under study with a view to establishing production in Australia to replace current imports and assess potential export possibilities. Generally each of these crops is small and would affect relatively few farmers. Collectively, however, they could significantly reduce our balance of payments problem. A case in point are the herbs and spices such as coriander, cumin, fenugreek, dill, fennel, aniseed and caraway. All these crops could be grown successfully in Australia by specialist producers and they have the potential to be the basis of an export industry worth some $10 million/year.

Pasture species

Programs concerned with the introduction of pasture species domesticated overseas, like those discussed earlier concerned with wild species, have in recent years given increasing attention to species which would improve the sustainability of our farming systems. Again the emphasis has been on the major problems facing many farmers - increasing soil acidity, rising water tables and poor persistence of many widely used legumes and grass cultivars under high and/or continuous grazing pressure.

New genotypes of existing crops

A retrospective analysis of the development of new genotypes of existing crops that produce innovative new products to meet new markets suggests that while our plant breeders have made some significant advances in this area, our overall track record is far from outstanding. Australia's breeding effort is heavily concentrated on the winter cereals - most other crops are poorly serviced. Further, there has been a trend in the past for all cereal breeders to concentrate on the same narrow class of varieties. For example, in the case of wheat, emphasis has been give to ASW/hard spring varieties. There has been little attempt to develop radical new sorts of wheat e.g. a soft, high protein, strong variety for starch/gluten manufacture.

Further, where we have been successful we have tended to follow the lead of others e.g. double zero canola varieties.

However, in recent years, there has been an increasing emphasis on developing new types of varieties of a range of crop plants that yield new products or meet new markets. Examples include the development of edible oil linseed (A. Green, CSIRO) naked oats for the chicken/pig feed industries (A. Barr, SADA) and naked barley for the feed market (Sparrow and Lance, Waite Institute) and red-seeded, winter feed wheat varieties for high rainfall areas of south-east Australia (J. Davidson, CSIRO).

One of the difficulties in developing innovative new genotypes of existing crop plants in the past has been the lack of suitable germplasm, and the difficulties using conventional breeding procedures of identifying or developing that germplasm. Clearly, the new biotechnologies based on recombinant DNA techniques, will open up many new opportunities in this area in the future. The prospect offered by these technologies in the medium to long term, is the widening of the potential gene pool of any species to include all life forms. In short, it holds the promise that we should be able to tailor the products of crop plants using genes from many sources to better meet our needs. There are many potential examples where radical alteration of the characteristics of crop plants would lead to new products or new uses. I will cite three examples (after Marshall (2)).

- Narrow-leafed lupins contain about 5 per cent oil which is below the economic threshold level for the use of lupins as a oilseed crop. However, if the oil level could be doubled or tripled then lupins would have the potential to be a major winter growing oilseed/protein crop. The fact that soybeans have approximately 20 per cent oil and peanuts around 50 per cent suggests that such a phenotype is physiologically possible and the relevant genes are available in these species to be transferred to lupins.
- Recent studies indicate that fish oils containing the long chain *n3* fatty acids, eicosapentaenoic (EPA, 20:5) and docosahexaenoic (DHA, 22:6) exert a protective effect in man against atherosclerosis and thrombosis by lowering blood cholesterol and triglyceride levels. To achieve these perceived benefits it is necessary to increase dietary intake of fish oil to a level equivalent to three fish meals/week. However, the world supply of fish is not great enough to sustain this level of demand. Hence, if a regular intake of these fatty acids is to be recommended as means of improving public health an alternative source needs to he found. These fatty acids are derived from the -linolenic acid and also occur in a range of marine and fresh water algae. Transfer of the genes responsible for the conversion of -linolenic acid to EPA and DHA from algae to a crop like linseed, which is high in -linolenic acid, could provide an important new crop as an alternative source of these fatty acids.
- In predominantly self-pollinated crops such as wheat, rice, barley and soybeans, an opportunity exists to increase yields 15-25% by the exploitation of heterosis. Attempts to exploit heterosis in these crops has met with at best limited success because of difficulties associated with the development of cost effective F_1 hybrid seed production systems. Apomix is, or more precisely agamospermy (asexual reproduction via seed formation), if it were available would allow the economic exploitation of hybrid vigour in these crops. Apomoxis is not common in higher plants but it is widespread and occurs in a range of species in 22 families. It is usually under relatively simple genetic control (two to three genes) and would therefore appear to be a prime target for genetic engineers.

Conclusions

The introduction and development of new plant species has been of fundamental importance to Australian agriculture. Opportunities still exist for the domestication of new species, especially in the case of Australian native flora in forestry and amenity horticulture, and for the introduction of new crops from overseas. However, the greater prospects are for the development of new genotypes of existing productive crops which produce new products or with new markets, especially as genetic engineering techniques become more generally available. It should be emphasized, however, that the production of new types of plants by whatever means requires a very substantial commitment of time and resources. Key factors in past successes have been the total commitment of one or more dedicated champions of each new crop and close interactions with industry and end users.

Table 1. Potential new industrial crops (after Princen, 1988).

Sources of long chain fatty acids

Crambe *(Crambe abyssinica)*

Certified seed of cultivars available but has failed to attract industry support.

Meadowfoam *(Limnanthes alba)*

Source of C_2, and $_{C22}$ acids. Active research programme at Oregon State University.

Sources of medium chain fatty acids

Cuphea *(Cuphea* sp.)

Potential source of C_8-C_{12} fatty acids. Active research programmes in the USA and Europe.

Apiaceae (formerly *Umbelliferae)*

Potential source of industrial oils. Several members of species including fennel have received some attention.

Sources of hydroxy fatty acids

Lesquerell a *(Lesquerellafendleri)*

The oils produced by this species, which contains unsaturated hydroxy fatty acids, have potential in coatings lubricates and plastics. Genetic and agronomic studies underway in Arizona.

Sources of epoxy acids

Vemonia *(Vernonia galamensis)*

Studied extensively in the USA as potential source of epoxy acids. Research now shifted to African nations near equator where the species has greater commercial potential.

Stokes aster *(Stokenia laevis)*

Indigenous to the Americas and produces an epoxy acid seed oil almost identical to that of Vernonia. Received some attention, but no long-term sustained study.

Sources of liquid wax esters

Jojoba *(Simmondsia chinensis)*

Now regarded as a commercial success with 40,000 ha in the USA and sizable acreages in other countries.

Sources of paper fibre

Kenaf *(Hibiscus camnabinus)*

This species has been under study for 30 years (20 years of production and processing research and 20 years of industrial evaluation) and is now regarded as a success. A mill is to be built in Texas and 10,000 ha of kenaf will be produced annually as feedstock for pulp and paper.

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