Invited Address

The key roles of seed banks in plant biodiversity management in New Zealand

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Abstract
The New Zealand flora is a mixture of indigenous and introduced species. The indigenous species have a high intrinsic value while the introduced species include all of the crop and pasture plants upon which the export-led economy depends. New Zealand must maintain both of these important sources of biodiversity in balance. Seed banks are useful tools for biodiversity management. In New Zealand, a seed bank for indigenous species has been a very recent initiative. By contrast, seed banks for introduced species have been established for over 70 years. The reasons for this discrepancy are discussed. For the economic species, conserved genetic diversity is used to enhance productivity and the environment. Large advances can be gained from species that are not used as economic plants. The gene-pool of white clover has been expanded by the use of minor species conserved as seeds in the Margot Forde Germplasm Centre.
Keywords: Seed banks, biodiversity conservation, New Zealand flora

Status and sizes of introduced and native floras

The New Zealand flora consists of a mix of indigenous and introduced plant species that occur mainly in separate ecosystems that are generally complementary, but can have tensions at the boundaries (Healy & Edgar 1980). The New Zealand indigenous flora is unique. There are approximately 1,800 species of seed plants (1,300 species of dicots, 470 monocots and 20 gymnosperms), with a high degree of endemism (Allan 1961; Moore & Edgar 1970; Webb *et al.* 1988; Edgar & Connor 2000). This native flora has both intrinsic and economic value and must be conserved because of its botanical uniqueness, importance in land stability and water quality and roles in providing the authentic New Zealand experience. The adventive flora is about the same size, consisting of approximately 1,420 dicots, 400 monocots and 30 gymnosperms (Healy & Edgar 1980; Webb *et al.* 1988; Edgar & Connor 2000; Heenan *et al.* 2008). In addition, there are over 30 000 introduced plant species in New Zealand that have not established self-sustaining populations (New Zealand Plant Conservation Network 2005). It is the adventive flora that supports the current New Zealand population of 4 million people by providing food and fibre, $13 billion of export earnings annually (New Zealand Official Yearbook 2008) and a significant contribution to the domestic economy, as reflected in its contribution to GDP. The role of introduced species in providing the unique tourist experience should not be under-estimated either, as many of our landscapes are composed of mixtures of adventive and native ecosystems. Because they are usually managed separately, the tensions between indigenous and adventive ecosystems can carry-over to the separate groups of people who manage them for differing outcomes.

One example is the importation and conservation of introduced plants, which is often seen as undesirable by the ecological community but essential to the economy by the agricultural community. The balance of this tension was altered when the government passed the Hazardous Substances and New Organisms (HSNO) Act (1996) that effectively made importation of new organisms difficult and expensive. This has placed plant importation largely on-hold, and it may be several decades before the potentially serious negative economic effects are realised. Meanwhile, the interactions between native and introduced species go on unaffected and we really need to ask ourselves if any of the conservation issues around the native flora have been altered by the legislation. We also need to recognise, as some of our most eminent botanists have (e.g., Healy & Edgar 1980) that the New Zealand flora is a mixed one, with different elements that should and can be managed together and not separately.

Biodiversity and ecosystems

Biodiversity is simply genetic diversity; but genetic diversity is not simple. The ecosystem is one level of classification of biodiversity. The 'species' is another level of classification of biodiversity, and there are various ways of defining species (e.g., Rieseberg & Willis 2007). Within a species, populations tend to be genetically differentiated among themselves by migration, mutation and selection. For natural and naturalised populations, the terms 'ecotype' and 'variety' are used to designate conspicuous inter-population diversity. However, genetic diversity is not always conspicuous, and the designation of place of origin is usually enough to suggest the likelihood of genetic diversity. For these, the terms 'provenance', 'collection' and 'accession' are used to suggest differences between native/naturalised plant populations of the same species, say, in the Manawatu or on Banks Peninsular. The geneticist tells us that these populations are likely to be genetically divergent. The conservationist recognises that keeping the seeds of just one of these populations will not do, because it is important to use locally adapted ('eco-sourced') genetic material if a local plant community has to be restored. There is strong genetic evidence that knowledge of place of origin is one of the strongest indicators of genetic diversity available to us. Research using molecular markers on 'core collections' (collections designed to represent the maximum amount of the genetic diversity of a species, but in a limited number of accessions) revealed that a collections with optimal eco-geographic representation usually show maximum genetic diversity (Ghamkhar *et al*. 2007).

The roles of seed banks in biodiversity conservation and management

Seed banks are an efficient way of conserving *ex situ* a huge amount of genetic diversity in a single room. The advantages are that about 90% of seed plants have orthodox seeds (seeds that are amenable to long-term storage under refrigeration at low temperatures), multiple collections can be conserved in a small space and database systems enable the recording of multiple eco-geographic details on each seed population. Seeds from seed banks can be used for both conservation and restoration of plant populations. Ideally, *ex situ* systems serve only as back-ups to *in situ* conservation systems, where biodiversity is maintained in living ecosystems, e.g., in national parks. However, idealism is not sufficient and, in New Zealand, seed banks are needed to play a significant part in securing against environmental and biological threats that cannot be covered by *in situ* conservation, as outlined below.

Rationale for a New Zealand native plants seed bank

A seed bank for endangered native plant species is a very recent initiative (2007) taken by the New Zealand Plant Conservation Network, with strong support from the Department of Conservation (DoC). The need for such a facility had been recognised in the New Zealand Biodiversity Strategy (Anon. 2000) in response to the fact that 120 vascular species/subspecies are acutely threatened with extinction, 94 are chronically threatened and a further 496 are at some risk (de Lange *et al*. 2004). It was also noted that future environmental changes, especially climate change, would exacerbate this problem. Although *in situ* conservation programmes are already underway for some species, other species are not covered. In addition, the *in situ* programmes are often not well documented and are also threatened by both environmental and biological risks.

Recognising that 92% of New Zealand vascular plants are seed-bearing species and, therefore, potentially amenable to long-term storage of dormant seed, it was sensible to recommend a move toward development of a seed bank. Based on the wider literature on seed banks, e.g., Linington (2003), it was anticipated that approximately 90% of species would have orthodox seeds and so be amenable to storage. Although there has been little research on the storage characteristics of New Zealand species (Hill 2004), the seed bank option nevertheless offered a potentially efficient solution. The primary objective is not to bank the whole flora, but to provide insurance support for the conservation of the most endangered species. This currently means about 50 critically threatened species that have orthodox seeds. A possible secondary role of the seed bank could be to store seeds harvested in good years for future restoration of populations. The seed bank was established in August 2007 by the New Zealand Plant Conservation Network, and is hosted by the Margot Forde Forage Germplasm Centre, AgResearch Grasslands Research Centre, Palmerston North and is initially sponsored by MWH (NZ) Ltd.

Rationale for New Zealand introduced species seed banks

Almost all of New Zealand's biological economy is based on plant species that are native to other countries, and the most suitable of these species are needed. This economy is highly vulnerable to multiple existing and emerging threats from pests, diseases and environmental changes, such as climate change. Progress in the development of new markets can also require new or different plants. These changes have previously required modification of, and will in the future require us to continually modify, the economic plants that we grow. To be fully effective, plant breeders need to be about 20 years ahead of these changes. Given our long distance from the sources of most of the key plant species, it can be difficult to access new genetic diversity quickly. Delays are exacerbated by the requirement under international agreements to negotiate with countries of origin, by biosecurity restrictions on arrival in New Zealand and by the time needed to develop populations that are adapted to local conditions. For these reasons, each of the major biological plant industries (forest, field crops, vegetables, horticultural, crops, pastures) has established collections of genetic resources (Forde *et al*. 1985). One of these is the Margot Forde Forage Germplasm Centre, a seed bank established in the 1930s as a crucial collection of the world's grassland genetic diversity. This diversity is immediately available to the pastoral industries and provides an insurance policy against future change.

The Centre currently holds seeds of over 80,000 entries of about 2,000 plant species. The collections have been developed and maintained for over 70 years. These have a monetary replacement value that is very high and cannot realistically be estimated. The collections are maintained and expanded according to industry and research needs. Seeds are distributed for plant breeding and for genetic/genomic and other research projects. Unique and valuable samples are identified and, where necessary, seeds are replenished. Seed imports are managed under permits from the Environmental Risk Management Authority (ERMA) and MAF Biosecurity.

Where possible, research on the genetic diversity of the collections is carried out and used to optimise the seed replenishment programme as well as to identify potentially valuable new genes for industry use. Diversity in pasture species is essential. Although ryegrass and white clover appear to predominate, there are many different genetic populations contributing to a very large amount of variation in these species. The best grass species or variety for a northern dairy farm is not the best for a southern sheep farm. The current best grass for that southern sheep farm will not the best be one in five years time because the pastoral environment is constantly changing – the climate, farming systems and pests change. New pasture plants are constantly needed and that is why we need the seeds here in New Zealand – now.

Some visionary scientists began this seed collection about 70 years ago. It is a crucial collection of genetic diversity – and an insurance policy against future change. It enables the New Zealand pastoral industries to respond to anticipated changes needed in the feed-base and prepare for the future. In a study commissioned by MAF Policy, Lancashire (2006) calculated that, in the last 30 years, overseas germplasm imported through the Centre has contributed over $700 million annually to the approximately $14 billion annual revenue from pastoral agriculture. International collections can also benefit the countries of origin, because seed samples are generally shared with those countries. Parallel values can be placed on the genetic resource collections of the other New Zealand biological sectors, although these are not entirely seed-based.

The contrasting roles of the New Zealand seed banks

Seed banks can be used for a range of purposes, including the following:

1. ‘species bank’ – to conserve species (generally back-up to *in situ* measures);
2. ‘population bank’ – to conserve genetic diversity within species (this sometimes includes population restoration);
3. ‘genome bank’ or ‘gene-pool bank’ – to conserve sets of related species that may be able to share genomes in a single gene-pool;
4. ‘breeding bank’ – to conserve selected families of interbreeding genotypes or
5. ‘gene bank’ – to conserve genetic stocks resulting from individual gene differences.

In the current New Zealand context, the new endangered species seed bank and the older introduced species seed bank have very contrasting roles. The endangered species bank is both a species bank and a population bank. It serves to conserve species that otherwise might be lost. It also stores seeds of regional populations so that regional diversity is conserved and restoration of local populations can be achieved in future. By contrast, the introduced species seed bank serves all of the purposes listed above. It is designed to provide the country with access to the maximum amount of genetic diversity of key species for economic use. Included among its key roles are the storage of seeds of so-called ‘minor species’, of breeding families and also genetic stocks.

Importance of minor species

The number of plant species sown in New Zealand pastures is fewer than 40. In fact, only three species, perennial and Italian ryegrasses and their hybrids, and white clover dominate the seed production statistics, with the remainder less used. As mentioned above, the germplasm centre stores seeds of nearly 2,000 different grassland species. What is the strategic value of storing over 1,900 species that are apparently unused? The primary reason is that such species can be of very high value.

First, they can be potentially useful in their own right, especially as environmental changes occur. For example, we need think only about climate warming to realise that subtropical grasses may soon be very useful components of New Zealand pastures (Crush & Rowarth 2007). The Margot Forde Forage Germplasm Centre has over 1,000 accessions of about 150 species of tropical and subtropical species stored ready for future use (Williams 1996). Another potential value of unused species could be for the development of new functions for future farm systems, e.g., carbon sequestration, mitigation of nutrient run-off. Although, in New Zealand, the numbers of newly domesticated agricultural species are low, the international research community is continually adding new species. For example, *Bituminaria bituminosa* var. *albomarginata* from the Canary Islands is being developed as a new perennial pasture plant in Western Australia for areas with annual rainfall as low as 250 mm (Real 2008). Second, so-called minor species may contribute to the gene-pools of already established species. It is in this area that minor species can play major roles in advancing genetic improvement of agricultural plant species.

Examples of the potential value of minor species

So-called minor species are often the wild relatives of important crop plants. They constitute the secondary and tertiary gene pools of these crops (Harlan & de Wet 1971). Examples of their use in enhancing the gene-pools of cereals and legumes have been reviewed by Dwivedi *et al.* (2008). There are some excellent New Zealand examples in barley breeding, where the wild barley species *Hordeum bulbosum* has been used to transfer multiple disease resistances to cultivated barley (Pickering & Johnstone 2005). Another wild relative, *H. vulgare* ssp. *spontaneum*, is also a source of disease resistances and drought tolerance. Similar principles are currently being used to expand the gene-pool of white clover. In this work, molecular phylogenetics has proved to be extremely valuable in determining the most likely closest relatives of white clover (Ellison *et al.* 2006). A group of 10 clover species and subspecies from Europe and Eurasia has been identified as ‘the white clover species complex’. These are all species that, on the basis of sequence analyses of nuclear DNA (internally transcribed spacer region of the 45S ribosomal repeats) and chloroplast DNA (the *trn*L intron) are closely related and, indeed, appear to have evolved as a species lineage (Table 1). Every one of these taxa has been crossed with at least one other in the species

Table 1 The ‘white clover species complex - *Trifolium* species and traits that can contribute to the gene-pool of white clover through wide hybridisation.

Species	Potentially useful traits
T. ambiguum	Rhizomes, deep roots, drought tolerance, pest resistances
T. uniflorum	Drought tolerance
T. occidentale	Drought, salt tolerance
T. nigrescens	Seed production, pest resistance, heat tolerance
T. isthmocarpum	Salt, water-logging tolerance
T. thalii	Rapid establishment, cold tolerance
T. pallescens	Cold tolerance

complex, indicating the potential for using interspecific hybridisation to transfer traits from species to species within the group (Williams *et al*. 2006). The primary gene-pool (the natural intra-specific genetic variation) of white clover lacks many potentially useful traits that are carried by other species in the complex (Table 1). These include deep roots, rhizomes, drought and heat tolerance, virus and nematode resistances, salinity and water-logging tolerance. The transfer of these traits by conventional hybridisation into the white clover gene-pool will ensure that new clovers can be bred that will be able to withstand climate change and other environmental pressures. In fact, the potential gains can be much greater even than this. Minor species frequently carry extremely useful genes that are masked, but which can contribute large genetic gains when transferred into the major species (Tanksley & McCouch 1997). It is likely that this will occur when white clover is crossed with its wild relatives. This is an example of not only how molecular techniques are enabling future plant breeding to be more efficient, but also of how apparently minor species tucked away in seed banks can contribute potentially very usefully to the future economy.

Conclusions

Seed banks play vital roles in ensuring the future of New Zealand's biodiversity. They provide the necessary protection for indigenous seed plant biodiversity as well as continuing access to the overseas biodiversity required for economic development of the biological export economy.

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