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Status of Australia's plant genetic resources

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Seed banks are integral in providing and conserving the plant diversity needed for future food production

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Foreword

Plant genetic resources are the raw materials that plant breeders use to develop new and improved plant varieties. This report is about the plant genetic resources that underpin Australia's cropping and grazing industries. Plant breeders require access to genetic resources to maintain and improve the yield of Australia's major crops and forages, such as wheat, barley, pulses, and the pasture grasses and legumes. Australia's grains and grazing industries rely on continual improvement of crops and pastures to help maintain and improve their productivity.

Five major seed banks in Australia provide and conserve plant genetic resources used by crop and pasture breeders. These seed banks hold some unique genetic resources and the largest global collection of temperate legumes.

Since this system of five seed banks was established in 1982, funding regimes for agricultural research and international arrangements for access to plant genetic resources have changed. Recognising this, stakeholders have been working toward an updated system of seed banks that better suits the current circumstances.

This report explains the importance of plant genetic resources to Australian agriculture. It also describes each of the major seed banks and their current status, and provides an account of recent activities aimed at consolidating the collections.

Phillip Glyde
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Summary

This report reviews the status of Australia's plant genetic resources, including their conservation and management status.

Plant genetic resources refer to the genetic diversity of plants as a resource. Seed banks provide and conserve the plant diversity needed for future food production. Without Australian-based seed banks, the genetic resources needed by plant breeders to generate new crop varieties would require repeated importation of seeds through quarantine. As this is an expensive and time intensive process, plant improvement would be delayed, potentially affecting the ability of primary producers to remain competitive in the international arena. Furthermore, timely access to seeds from overseas cannot always be guaranteed.

Australian seed banks hold significant collections that are not held elsewhere. For example, Australian seed banks have conserved early wheat and barley collections and unique land races or older cultivars that are now proving invaluable in modern breeding. These seed banks house the world's largest temperate legume collection with 40 000 unique genetic lines. Australia also has native relatives of important crop plants, with unique genes adapting them to Australia's challenging environment.

Australia's major plant genetic resource collections together comprise 184 000 'accessions' (documented samples). These collections are not only critical for Australian agriculture, but also significant in a global context. Researchers and breeders constantly use the germplasm from domestically held seed banks, with over 14 000 accessions distributed annually to Australian users. Overseas users request approximately 3000 accessions annually.

Agricultural research and development investment in Australia through public investment by the research and development corporations, particularly the Grains Research and Development Corporation, and state governments is increasingly being directed to 'upstream' and more strategic research and pre-breeding such as molecular plant breeding. Australian seed banks hold the genetic resources used in molecular approaches, enabling novel and targeted plant breeding.

Following a review of plant genetic resources centres in Australia in 2007, the Primary Industries Ministerial Council resolved that a National Genetic Resources Centre be established. The Primary Industries Ministerial Council noted that the establishment of a National Genetic Resources Centre would place Australia's plant genetic resources collections on a more secure footing and achieve improvements and efficiencies over the existing five state-based seedbanks. The Primary Industries Steering Committee also agreed, in principle, to a 'two-node model' option for the National Genetic Resources Centre. Plans for establishing, funding and maintaining the National Genetic Resources Centre are under development.

1 Plant genetic resources for food and agriculture

What are genetic resources?

Plant genetic resources, or 'germplasm', is a term referring to the genetic diversity of plants as a resource. Genetic diversity among individuals of a species resides in populations, existing either in natural ecosystems or in human-made situations—on farms or in storage systems.

To make use of genetic diversity, plant breeders require access to genetic resources from the wild (natural habitats of the species in question) and/or from repositories established to store diverse genetic resources.

Repositories usually take the form of seed banks, but can also be living plant collections, for example a collection of mango tree varieties. More recently, genetic diversity can be maintained, and may be more appropriately maintained, as tissue cultures (for example, banana tissue cultures) or as deoxyribonucleic acid (DNA) samples (for example, at the Australian Plant DNA Bank in Lismore).

Historically, the plant genetic diversity important for food and agriculture has comprised those species directly used by humans for food, feed, fibre and timber. In recent decades, as plant breeding has become more sophisticated, more species that are closely related to agricultural species (such as wheat) have been used as sources of novel genetic diversity. The term 'genetic resources' has therefore come to mean more than simply just 'seeds'. The term seed bank is also meant in general terms to include germplasm.

The way modern technology has changed the breadth of the 'genetic resources' concept is recognised in the use of terms in the 2001 International Treaty for Plant Genetic Resources for Food and Agriculture:

Plant genetic resources for food and agriculture means any genetic material of plant origin of actual or potential value for food and agriculture ...

Genetic material means any material of plant origin, including reproductive and vegetative propagating material, containing functional units of heredity.

These definitions are based on those of the Convention on Biological Diversity for genetic resources and genetic material (Convention on Biological Diversity United Nations 1992, FAO 2009a).

Assured access to genetic resources underpins Australia's ability to maintain agricultural productivity in the face of environmental and economic challenges. Farmers and plant breeders rely on access to genetic resources to improve the quality and productivity of crops and pastures. This report reviews the conservation and management status of Australia's plant genetic resource collections. The focus of the report is genetic resources in relation to seed crops.

Why is genetic diversity important?

Genetic diversity is fundamental to life, because at a species level it enables a breeding population to survive in space and time by being able to adapt to changing environments and selection pressures.

Plant genetic diversity is critical for food and agriculture because it enables plant breeding to be used to alter crop, pasture and forest species to meet changing environments and needs. This adaptation

is critical for food security through maintaining or increasing production of plant-based agricultural systems.

Continuous modification of agriculturally important plant species is required for a range of reasons. These include:

- adapting to environmental stresses (drought, heat, frost, waterlogging, salinity, climate change)
- protecting plants against continually evolving pests and diseases, and new ones
- increasing yields
- improving food, feed, fibre or timber quality
- modifying plants structurally to suit farming or harvesting systems.

The global and Australian context of plant genetic resources for food and agriculture—food security

Although food production is sufficient to meet global demand, the number of people suffering from hunger and poverty exceeds one billion. The world's population is predicted to reach 9.1 billion by 2050 (Godfray et al. 2010). Feeding these people will be an unprecedented challenge (Ash et al. 2010). To meet the demands of this larger, more urbanised, and richer population will require increasing food production by about 70–100 per cent (FAO 2009b; Godfray et al. 2010).

In the past, the solution to food shortages has been to bring more land into primary production and to increase yields (intensification). However, the amount of arable land globally has not appreciably changed in more than half a century, and it is unlikely to drastically increase in the face of urbanisation, increased salinity and desertification (Fedoroff et al. 2010). Increasing productivity through plant improvement will remain a major strategy for meeting the demand for increased food production (Godfray et al. 2010). In addition to increasing demand for food, Australia is facing significant environmental and sustainability challenges.

The agriculture sector will need to adapt. It can do this through a range of strategies intrinsically linked to the availability of plant genetic resources for food and agriculture. These include adapting current crops and pastures, and growing alternative crops and pastures.

Plant genetic resources are the raw material that farmers and plant breeders use to improve the quality and productivity of crops and pastures. Plant genetic resources hold the genetic diversity that underpins future food production and agriculture. Australian agriculture is based largely on exotic plant species, in particular crop species and improved pasture species.

It is important to ensure that plant genetic resources will be available for research and plant breeders, and be conserved for future generations. The future of agriculture globally depends on international cooperation, and on the continued open exchange of plant genetic resources, and as such depends on the genetic diversity within these crops from other countries and regions. Exchange of genetic resources needs to continue to ensure that crop improvements can be made in future. The International Treaty on Plant Genetic Resources for Food and Agriculture (the treaty) was negotiated to ensure future access to plant genetic resources for food and agriculture.

The treaty and Global Crop Diversity Trust

The United Nations Food and Agriculture Organization (FAO) adopted the International Treaty for Plant Genetic Resources in November 2001, and it came into force on 29 June 2004. Australia ratified the treaty in December 2005.

This legally binding treaty (under the auspices of the FAO) covers all plant genetic resources relevant to food and agriculture. The treaty objectives are the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of benefits derived from their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security. The treaty is intended to assist the 'facilitated access' to and sharing of the benefits of such resources. 'Facilitated access' means, in most cases, unrestricted access to plant genetic resources for food and agriculture at minimal cost.

The treaty aims to make it easier for plant breeders to access existing plant genetic resources (for example, seeds and, tissue cultures) held in genetic resource centres to create new varieties. This easy access to a wide range of plant genetic resources is critical to allow breeders to develop new improved varieties with traits such as pest and disease resistance, the ability to cope with other environmental stresses, increased yields, and added consumer health benefits. Easy access to the widest possible range of plant genetic resources will also facilitate the development of varieties that could lead to the expansion of arable land and the extension of growing seasons.

The treaty provides an integrated approach to the conservation and sustainable use of plant genetic resources for food and agriculture, and benefit sharing relating to them. It may become a key element in setting policy directions and priority activities in genetic resources.

Parties to the treaty have agreed to establish an efficient, effective and transparent Multilateral System to facilitate access to a set of plant genetic resources for food and agriculture, and to share the benefits in a fair and equitable manner. Annex 1 of the treaty lists approximately 95 food and forage species that constitute the core species of the system.

The Multilateral System, rather than a specific provider country, is the source for genetic material accessed under the treaty for use in research, breeding and training, and in conservation.

By signing the treaty, countries are obliged to place collections of plant genetic resources that are under the management and control of the national government and are in the public domain into the Multilateral System. Parties to the treaty also have a responsibility to encourage other organisations in their jurisdictions to place their seed collections into the system.

At the same time, treaty signatories gain access to the genetic resources of all other signatories, as well as to centres of the Consultative Group on International Agricultural Research (CGIAR). This is a more efficient system than having to establish multiple bilateral (government-to-government) agreements. The treaty also constitutes governmental approval for seed banks to exchange germplasm without constant reference to governmental authorities.

The benefits of the treaty flow to:

- consumers (greater variety of foods and agricultural products, increased food security)
- the scientific community (guaranteed access to breeding resources)
- International Agricultural Research Centre seed banks (collections are placed on a safe and long-term legal footing)

- the public and private sectors (greater access to a wide range of genetic diversity)
- the environment (conservation of critical resources)
- developing countries, in particular those that have ratified the treaty.

The benefits to treaty member countries include guaranteed access to plant genetic resources for their food production, research and development; eligibility to share in the benefits arising out of the use of resources held under the Multilateral System; and eligibility for financial support.

Contracting member countries are responsible for incorporating the objectives of the treaty in their national plans and programs; according due priority to building national capacity in plant genetic resources for food and agriculture; increasing awareness of the Multilateral System; and enhancing confidence in the Standard Material Transfer Agreement. This agreement is a contract for the transfer of genetic resources from the Multilateral System, which includes clauses outlining the rights and responsibilities of those receiving material from the Multilateral System. All transfers of plant genetic resources for food and agriculture from the International Agricultural Research Centre will be subject to the Standard Material Transfer Agreement adopted by the governing body of the treaty at its first session in June 2006.

Global Crop Diversity Trust

The Global Crop Diversity Trust (the trust) is an autonomous fund organised under international law. The FAO and the CGIAR serve as co-sponsors, and each hosts offices for the trust. The objective of the trust is to 'ensure the long-term conservation and availability of plant genetic resources for food and agriculture with a view to achieve global food security and sustainable agriculture'.

The trust is an essential element of the treaty's funding strategy. It works by raising funds, investing them conservatively, and using the income to provide support to existing institutions in furtherance of the trust's goals. The trust supported the development of a set of conservation strategies that guide the allocation of resources to the most important and needy crop diversity collections. To date Australia has donated \$25 million to the trust.

The Australian Government Department of Agriculture, Fisheries and Forestry has carriage of Australia's engagement with the treaty. Together, the treaty and the trust form the international instruments for the conservation and sustainable use of plant genetic resources for food and agriculture.

Conserving and managing genetic diversity for food and agriculture involves many approaches. The goals listed in the treaty can be summarised as follows:

Conserving

- conserve plant genetic resources for food and agriculture outside their natural habitat (*'ex situ'*), in seed banks, living plant collections or DNA banks
- collect threatened or potentially useful plant genetic resources for food and agriculture (together with relevant data on them), and conserve them *ex situ*
- promote *in situ* conservation, including the maintenance and recovery of viable populations of species in their natural surroundings, and, in the case of domesticated or cultivated plant species, in the surroundings where they have developed their distinctive properties

- conserve wild crop relatives, wild plants for food production, and ecosystems and natural habitats relevant to food and agriculture, including those in protected areas, and support the efforts of indigenous and local communities to do so
- promote and support efforts by farmers and local communities to manage and conserve plant genetic resources for food and agriculture on-farm
- survey and inventory plant genetic resources for food and agriculture *in situ*, taking into account the status of existing populations and the degree of variation within them, and (as feasible) assess any threats to them
- minimise or, if possible, eliminate threats to plant genetic resources for food and agriculture *in situ*.

Managing/operational

- maintain and promote further development of an efficient and sustainable system of *ex situ* conservation, giving due attention to the need for adequate documentation of plant genetic resources, information systems, and characterisation, regeneration and evaluation of these resources
- broaden the genetic base of crops and other agriculturally important species
- promote the development and transfer of appropriate technologies for *ex situ* conservation
- monitor the maintenance of the viability, degree of variation, and the genetic integrity of collections
- undertake and strengthen research that enhances and conserves biological diversity, by maximising intraspecific and interspecific variation
- promote, where appropriate, the expanded use of local and locally adapted crops, varieties and underutilised species
- pursue agricultural policies that promote, as appropriate, the development and maintenance of diverse farming systems that enhance the sustainable use of agricultural biological diversity.

2 The need for seed banks— conservation and management

Intensification of agriculture, industrialisation, expanding human populations and associated habitat disturbance and degradation have all taken their toll on the genetic diversity of agriculturally important species. Genetic diversity has been lost both on farm and off farm.

Rapid loss of genetic diversity in the 20th century prompted the establishment of seed banks worldwide. Seed of current and old cultivars and land races (ancient or primitive regionally adapted cultivated varieties of a crop plant) are lodged in seed banks. Seed collecting expeditions continue to be made to areas of the world where species diversity was or is high, so that representative genetic diversity can be conserved.

A collection of a particular variety or race of a species, or from a particular geographic area of a species range, or representing in some other way a discrete subset of the genetic diversity of a species, is known as an 'accession' (a documented sample). The genetic diversity of an individual plant species therefore comes to be represented by many accessions (sometimes hundreds or thousands) in diverse seed banks. This aims to achieve a broad representation of the genetic diversity of the species. Seed banks in different countries store duplicate collections across both national and international seed banks to minimise risk of loss of genetic material.

Seed banks are a convenient and relatively inexpensive form of genetic resources conservation. Seeds are naturally dormant phases of a plant's life cycle, are often small and easy to store, and will remain viable for many years (sometimes decades or even longer) if stored in an optimal way. It may be more appropriate to store some species, for example trees or plants that also (or only) reproduce vegetatively, as living plants, or as tissue culture where species or varieties are sterile. In addition, where diversity has been documented at the DNA level, storage as DNA may be preferable and more convenient. Samples of this type can be used as a reference material or as a source of specific genetic material for use in genetic modification programs.

The conservation of genetic resources away from the natural habitat (that is, in seed banks, as living collections, or as tissue culture or DNA), is known as '*ex situ* conservation'. Conservation of genetic resources in the natural habitat remains important, to maximise the diversity that is conserved. The term '*in situ* conservation' refers to the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated plant species, in the surroundings where they have developed their distinctive properties. The latter includes conservation 'on-farm' and is an important facet of the International Treaty for Plant Genetic Resources for Food and Agriculture, which supports *in situ* conservation of plant genetic resources, particularly in traditional farming systems in developing countries.

In situ conservation also allows the current evolutionary forces to work on existing genetic diversity in the field. Seed samples in *ex situ* collections represent the product of genetic diversity and the prevailing evolutionary forces up until the point when the samples were first collected. Subsequent regeneration of those accessions in the seed bank is aimed at maintaining the state of the genetic diversity within each accession.

Seed banking

Seed banking is the usual method of plant genetic resources conservation. Seeds are in a dormant metabolic state and usually genetically programmed to remain viable for long periods of time. The longevity of seeds of most species can be increased by drying them further, and storing them below zero °C under disease-free and insect-free conditions.

Seed banking is also relatively cheap and convenient compared with other forms of conservation such as tissue culture and cryopreservation. The FAO estimates that about 90 per cent of the 6 million plant accessions in global *ex situ* collections are conserved in seed banks.

Seeds are dried to low moisture content and stored at subzero temperatures in cold stores (usually about minus 2 to minus 4 °C for material to be accessed in time frames of 5–10 years) or in deep freezers (usually minus 20 °C) for longer-term storage. Methods of preparation for storage are becoming increasingly sophisticated, for example tailoring the amount and speed of drying to the species in question and checking for unviable or diseased seeds using X-rays or other imaging techniques.

Accessions need to be periodically monitored for 'viability testing', by taking representative subsamples of the accession for germination testing. In addition, the accession needs to be periodically regenerated to provide enough seed to supply users and replace the core seed stock. This is generally referred to as 'seed increase'. Regeneration needs to be done in a controlled way to maintain the genetic variability of the specific accession.

Information about the accession is critical to its value; therefore documentation and other information about the accessions are entered into a database. A large number of information systems have been established across the diverse network of global seed banks, each with their relative merits and drawbacks.

Documentation needs to record at least minimum information on name of the species, variety or cultivar, the provenance (where the material was sourced), date of collection, geographic source of the material, and some basic information about the environment of that area (such as climate, soil and habitat).

In addition, the accession is described as much as possible. This so-called 'characterisation' is often done by the seed bank itself or by external parties if resources permit. All accessions need to be given a unique identifier, and in sophisticated systems this may include barcoding of the accession.

Accession information is at least a morphological description of the accession, but any other kind of information could be lodged in the database, including molecular genetic information and new information generated by researchers and other users. Information is organised to promote integrated management of the genetic resources, including characterisation and evaluation. The database and accession information can be cross-linked with other databases, information systems and data sources (such as climate and soil data) thus extending the value of the accession.

Seed banks are not just stored collections

Seed banks have two principal functions. First, they preserve genetic diversity—particularly genetic diversity within species, but also species diversity. Seed banks ensure that the varieties and land races of economically important species and their wild relatives that underpin food supply and other uses we make of plants are secure for both current and future generations.

Second, seed banks conserve and manage genetic diversity for use by plant breeders, researchers and farmers. Seed banks provide these users with access to genetic resources. Access ensures that efforts to adapt agriculturally and economically important plants to changed environments' and to meet changing demands can continue. This underpins innovation, agricultural development, productivity and sustainability, and therefore, ultimately, food security.

Seed banks, when adequately funded, are dynamic institutions, actively expanding the diversity they hold and distribute, enhancing the quality and longevity of their genetic resources, and expanding the information about their holdings.

Security of conserved seed requires multiple backups

Issues of particular importance are rapidity of access and cost of importation. In Australia for example, with its necessary and robust quarantine arrangements, it would take one or two years to process an accession from overseas through quarantine, and there is no guarantee of successful entry.

While most germplasm stocks are also held in other national or international collections, at least as backup collections, there are significant logistics, administration, and material transfer agreement requirements to be met in acquiring and importing germplasm from overseas. Imported seed then needs to be regenerated or bulked up to make it available to breeders. It could end up taking a decade or longer to complete the reimportation of an accession, given current staff and facility resources.

Users of germplasm material prefer to access material from Australian seed banks as it saves money and time, both of which are important for a typical five-year breeding program.

Maintaining and accumulating collections domestically builds up a rapidly available national collection of accessions in the public domain, which are immediately accessible to users because they have already been cleared through quarantine, characterised and bulked up.

General issues of plant genetic resources for food and agriculture

Significant and complex policy, legal and access issues will only be identified in this report and not covered in detail. However, some detailed consideration will be given within the context of the Australian plant genetic resources requirements and the need to establish an Australian national framework for the conservation and management of plant genetic resources.

Policy, legal and access issues that affect plant genetic resources for food and agriculture include:

- governance regimes
- access regimes
- benefit sharing regimes
- legal ownership of collections and intellectual property rights (including plant variety rights and plant patents)
- the interface of access and benefit sharing regimes for plant biodiversity (that is, native plant species biodiversity)
- relevant international agreement obligations, notably under the International Treaty for Plant Genetic Resources and the Convention on Biological Diversity

- public and private plant genetic resources for food and agriculture and funding arrangements
- the choice of information management system for plant genetic resources for food and agriculture collections and information.

Plant genetic resources in Australia

The issue of how to secure, consolidate and improve the conservation and management of plant genetic resources for ensuring Australia's farming future and food security has been considered for many decades. Consideration at a national and intergovernmental level started in about 1976, when there was a proposal to the then Plant Protection Committee to form an expert panel on genetic resources.

This led to the formation of a Joint Expert Panel on Genetic Resources, which was intended to develop national policies to be implemented through the committee. In 1982, the major plant genetic resources collections were established and their collections made into national collections. These are:

- the Australian Winter Cereals Collection (Tamworth, NSW)
- the Australian Temperate Field Crops Centre (Horsham, Victoria)
- the Australian Tropical Crops and Forages Collection (Biloela, Queensland)
- the Australian Medicago Genetic Resource Centre (Adelaide, South Australia)
- the Australian Trifolium Genetic Resources Centre collection (Perth, Western Australia).

Hereafter, referenced by town (Table 1).

There have been various other attempts since 1982 to set genetic resource centres on a secure footing. One of the difficulties in securing an adequately resourced national framework for plant genetic resources for food and agriculture has been funding. The 1982 initiative eventually resulted in significant activities toward establishing a national framework.

Table 1 Australian seed banks and their locations

Seed bank location	Collection title	Main holdings
Tamworth	Australian Winter Cereals Collection	wheat, oats and barley
Horsham	Australian Temperate Field Crops Centre	temperate pulses (grain legumes) and oilseed crops
Biloela	Australian Tropical Crops and Forages Collection	primarily tropical forages, grains, grasses and legumes
Adelaide	Australian Medicago Genetic Resource Centre – now the South Australian Research and Development Genetic Resource Centre	primarily <i>Medicago</i> and other pasture species
Perth	Australian Trifolium Genetic Resources Centre collection	primarily <i>Trifolium</i> species and other legume forages
Canberra ^a	Australian Indigenous Relatives of Crops Collection (inactive)	Indigenous relatives and backup of other seed banks

Note: ^a The Canberra seed bank, although not part of the 1982 formation of the plant genetic resource centres, provides backup storage for the five major seed banks.

For Australia, full assessment of the status of the varied and complex measures relevant to the conservation and management goals would take much time and effort. Ideally, there should be an integrated approach in Australia to the exploration, conservation and sustainable use of plant genetic resources for food and agriculture, but there is currently no central national focus or body for integration. By far the most significant determinant of the conservation and management status of Australian plant genetic resources for food and agriculture is the level of resources applied to both *in situ* and *ex situ* conservation.

Management status of Australian seed banks—current status of *ex situ* conservation

The five main Australian genetic resource centres each effectively operates as a national facility for the species under their respective mandates. The centres' species mandates (decided in 1984) are wheat, barley and oats (Tamworth Seed Bank); primarily pulses and oilseeds (Horsham Seed Bank); primarily tropical forage grains, grasses and legumes (Biloela Seed Bank); primarily *Medicago* and other pasture species (Adelaide Seed Bank); and primarily *Trifolium* species and other legume forages (Perth Seed Bank).

The total plant genetic resources for food and agriculture collection in the five major seed banks comprises about 187 000 accessions (Auricht et al. 2009), compared with 184 000 accessions in 2007. The collection is larger than the Brazilian Agricultural Research Corporation gene bank (102 000 accessions), cited in 2004 as the world's seventh largest. The US gene bank holds more than 460 000 accessions and is the largest in the world. Australia's collections are therefore not only critical for Australian agriculture, but also significant in a global context. Australian and overseas researchers and breeders constantly use the resources, with over 14 000 accessions distributed annually to Australian users and 3000 to overseas users.

The status of Australia's *ex situ* conservation of plant genetic resources for food and agriculture is best summarised by describing the holdings of Australia's seed banks, which fall into two main categories: those dedicated to supply such resources for plant improvement for agriculture, and those dedicated to native species conservation.

Tamworth Seed Bank (Australian Winter Cereals Collection Tamworth, NSW)

The Tamworth Seed Bank is a grain crops collection, holding primarily wheat (*Triticum*, *Secale*, *Triticosecale*, *Aegilops*, *Agropyron* and their hybrids), barley (*Hordeum*) and oats (*Avena*) germplasm. These crop genera are the most valuable grain crops in Australia, in terms of both gross value of production and export commodities value.

In 2007, total accessions of these three crops comprised:

- about 36 000 'wheat' accessions (including *Triticum*, *Aegilops*, *Agropyron*, *Secale*, and *Triticale*)
- about 12 500 barley (*Hordeum*) accessions
- about 5600 oats (*Avena*) accessions.

Auricht et al. (2009) recently updated accessions, characterisation and distribution information about the five major seed bank collections in Australia, recording total accessions in the Tamworth collection at 54 317.

The Tamworth Seed Bank includes a mix of varieties, cultivars, breeding lines, weedy relatives, traditional cultivars/land races; and research, mutant and non-cultivated accessions from all over the world. About 25 per cent of the land races held are unique to the Tamworth Seed Bank.

The collection includes vitally important germplasm for Australia's wheat, barley and oat breeding programs. It contains a number of special collections for example, Asia-Caucasus; material collected by Tamworth Seed Bank staff over the years, and diverse wheat lines from the International Maize and Wheat Improvement Centre collection in Mexico (CIMMYT—Centro Internacional de Mejoramiento de Maíz y Trigo, see www.cgiar.org). It also contains the Watkins collection, an old collection of wheat lines secured from the John Innes Centre (Norwich, United Kingdom). This collection is maintained as populations, while at the John Innes Centre it is maintained as pure lines, resulting in divergence of the genetic diversity of each collection.

The Tamworth Seed Bank provides a good example of the links national seed banks need to maintain internationally to gain access to the germplasm most relevant to Australia's crop breeding needs. The seed bank has links with gene banks in Russia, the United States, Canada, Mexico, the Czech Republic, Germany, Sweden, Syria, China, the United Kingdom, Georgia, Armenia, Azerbaijan, Uzbekistan, Kazakhstan, and Tajikistan. The strength of such links needs to be maintained through regular contact and exchange of material in order to meet the germplasm needs of the wheat industry.

A significant genetic resources initiative funded by the Grains Research and Development Corporation (GRDC) in recent years has been the CIMMYT/GRDC program, in which lines stored in CIMMYT are being introduced to the Tamworth Seed Bank in order to secure germplasm vital to Australia's interests.

Another initiative involving the Tamworth Seed Bank is its development of the Focused Identification of Germplasm Strategy, which aims to provide for more efficient and effective identification of germplasm most likely to possess traits desired for particular purposes. The strategy involves:

- climatic and environmental profiling of the geographic sites from which collections are made
- identification of collections most likely to possess traits suited to particular needs
- subsequent development of a 'core set' of all of the Centre's collections as the set that is most likely to contain most of the genetic traits needed by plant breeders.

Horsham Seed Bank (Australian Temperate Field Crops Collection, Victoria)

The Horsham Seed Bank is primarily a temperate pulses and oilseeds crops collection, including pea (*Pisum*), chickpea (*Cicer*), rapeseed (*Brassica*), vetch (*Lathyrus*), lentil (*Lens*), linseed (*Linum*), bean (*Vicia*), safflower (*Carthamus*), and miscellaneous crops accessions. Auricht et al. (2009) recorded Horsham Seed Bank's total holdings at 34 011 accessions.

The first class is the A collection, made up of lines that will play a major role in breeding throughout the industries. These lines consist of land races, wild material, and pest and disease resistant material. Lines accessioned to the A collection are bulked up through field regeneration, and stored both in working and long-term storage at the Horsham Seed Bank and backed up at the Canberra Seed Bank. The states pay the CSIRO storage fees for this backup capacity at the Canberra Seed Bank.

The B collection is made up of lines that may one day be added to the A collection if these are likely to benefit industry. Lines that are accessioned in the B collection will be processed through post-entry quarantine as before and distributed to the customers; residual seed is placed in the Horsham Seed Bank's working storage unit (2 °C), kept until requested, or added to the A collection. If the line

is not requested within its shelf life (approximately 10 years), the material is discarded to make way for newly acquired lines.

The Horsham Seed Bank has incomplete coverage of the wild relatives of its mandated crops. The Horsham Seed Bank's current wild relatives collection comprises 450 wild relatives of pea, lentil and chickpea, some of which are reselections of original accessions, and also approximately 1000 relatives of *Brassica* crops. Although the number of wild Brassica-related genera is large, not all related genera are represented in the Horsham Seed Bank.

The Horsham Seed Bank collection of wild pulses is less than half such accessions held at the CGIAR seed bank at the International Center for Agricultural Research in the Dry Areas in Syria. It also has a smaller range of species of *Cicer*—for example, more than 30 perennial species are not in the Horsham Seed Bank collection, partly due to past failure of attempts to reproduce the material in the Department of Primary Industries Victoria quarantine facility. Coverage of accessions from relevant, stressful environments such as those of high salinity, or for special characteristics such as reproductive frost tolerance needs to be improved.

The most recent collection initiative was joint collecting of pea and faba bean germplasm in China, funded through an Australian Centre for International Agricultural Research project. This material (about 100 accessions of each species) was collected in previously unsampled areas in the Yunnan and Qinghai provinces, mostly at 1500–2200 metre elevation. These collections are of unknown potential and remain to be characterised, but since they come from high elevation, they are candidate sources for cold/frost tolerance.

A number of the accessions held at the Horsham Seed Bank are unique: many land races or wild relatives are no longer available in cultivation or in traditional habitats, and exist only in *ex situ* collections. Recent collection trips in China found that farmers were in transition, switching from traditional land races to modern pea and faba bean varieties.

Biloela Seed Bank (Australian Tropical Crops and Forages Collection, Queensland)

The Biloela Seed Bank is a significant collection in several ways. First, it is the primary Australian collection of tropical plant genetic resources for food and agriculture. Second, it is a very diverse collection in terms of genera and species, and third, it includes a strategic collection of indigenous relatives of crop species. Auricht et al. (2009) recorded the Biloela Seed Bank's total holdings as 39 653 accessions.

As well as holding accessions of tropical crops germplasm, the Biloela Seed Bank also has an extensive tropical forage grasses and legumes collection (both annual and perennial species), diverse fibre crop holdings, and a collection of horticultural, herb and spice germplasm. The collection includes the CSIRO Division of Tropical Crops and Pastures collection, which the Queensland Department of Employment, Economic Development and Innovation agreed to take over after the CSIRO withdrew from seed bank operations in Brisbane.

Tropical field crops include adzuki, amaranth, coriander, cotton, cowpea, culinary bean, guar, kenaf, maize, millets, mung bean, navy bean, peanut, pigeon pea, sesame, rice, sesbania, sorghum, soybean, sunflower, tobacco, tomato and winged bean.

Tropical forage species of grasses, legumes and shrubs include *Aeschynomene*, native *Brachiaria*, *Cenchrus*, *Centrosema*, *Desmanthus*, *Digitaria*, *Leucaena*, *Macroptilium*, native *Panicum*, *Stylosanthes* and *Urochloa*. The 11 000 accessions of tropical forages collected from Africa, Americas and Asia are significant because half of the accessions are not held by any other seed bank in the world.

The centre has taken a lead in assembling, cataloguing and regenerating the indigenous wild relative collections of millets (such as *Sorghum*, *Pennisetum* and *Cleistachne*), mung bean and cowpea (*Vigna*), pigeon pea (*Cajanus*), tobacco (*Nicotiana*), rice (*Oryza*) and cotton (*Gossypium*). These indigenous wild crop relatives constitute a significant Australian contribution to global plant genetic resources.

Adelaide Seed Bank (South Australian Research and Development Institute Genetic Resources Centre, Urrbrae, South Australia)

In 2007 the Adelaide Seed Bank, hosted by the South Australian Research and Development Institute, held 38 904 accessions of annual and perennial temperate pasture legumes, including *Astragalus*, *Hedysarum*, *Lotus*, *Medicago*, *Melilotus*, *Onobrychis* and *Trigonella*. Auricht et al. (2009) recorded the Adelaide Seed Bank's total holdings as 41 490 accessions.

The seed bank maintains the world's largest collection of *Medicago* and temperate pasture legume species and has a substantial collection of salt tolerant and native fodder species. The Adelaide Seed Bank collection is an invaluable collection, particularly of *Medicago* species, because 95 per cent of the accessions are not represented in any other collections in the world.

Pasture legume accessions were collected predominately from alkaline and saline soils in the Mediterranean and surrounding regions by Australian scientists over the last 50 years and are unique to the Adelaide Seed Bank collection. There is also a smaller collection (2000 accessions) of temperate forage grasses, and salt tolerant herbs and shrubs.

The Adelaide Seed Bank is a member of the international *Medicago* Stock Centre Project. It is dedicated to serve as the Asian Pacific resource centre for the *Medicago truncatula* genomic collections that have been created by various laboratories worldwide. *Medicago truncatula* is the model legume species in a worldwide effort to DNA sequence and understand the genome of this important group of plants. Its relative *Medicago sativa*, otherwise known as lucerne or alfalfa, is an important fodder crop. In an agricultural context, legumes fix atmospheric nitrogen through a symbiotic relationship with bacteria and also produce high protein, nutritious fodder or grains.

In 2007, the centre held 1678 accessions of annual *Trifolium* and *Vicia* accessions (the vast majority are *Trifolium*), and maintained working collections of around 800 accessions of salt-tolerant species of *T. balansae* and *T. resupinatum*. The centre was supported by the then Cooperative Research Centre (CRC) for Plant Based Management of Salinity, whose salinity work has some continuity in the Future Farm Industries CRC.

The Adelaide Seed Bank has detailed its holdings in the context of the International Treaty on Plant Genetic Resources for Food and Agriculture and species listed in Annex 1 of the treaty. Altogether, 13 834 Annex 1 forage legume and shrub species are maintained at the Adelaide Seed Bank. The centre also hosts small holdings of 860 historical accessions of Annex 1 forage grass species.

Perth Seed Bank (Australian Trifolium Genetic Resource Centre, Western Australia)

In 2007 the Perth Seed Bank, hosted by the Western Australian Department of Agriculture, held 17 500 accessions of *Trifolium*, *Ornithopus*, *Biserrula*, *Dorycnium* and other temperate pasture legumes adapted to acid soils. Auricht et al. (2009) recorded the Perth Seed Bank's total holdings as 17 506 accessions.

This collection of pasture legumes, collected mostly from the Mediterranean, is significant because most species are poorly represented in *ex situ* collections in the countries of origin. The collections of

annual *Trifolium* and *Ornithopus compressus* are of particular significance. The *Trifolium* collection is used extensively in the National Annual Pasture Legume Improvement Program.

The other major collection of *Trifolium* in the world is held at International Center for Agricultural Research in the Dry Areas, whose germplasm is mostly from Syria, Jordan and Tunisia, with some from Morocco and Algeria. This collection at the International Center for Agricultural Research in the Dry Areas and the much larger collection at the Perth Seed Bank together form the most important *ex situ* germplasm collection of Mediterranean *Trifolium* in the world. The collection of yellow serradella held in Perth is also the most comprehensive and important collection in the world.

Trifolium, *Ornithopus*, *Biserrula* and other species generally adapted to acid soils have application to many parts of southern Australia. Many of the cultivars developed from germplasm held in Perth enjoy commercial success across southern Australia. *Ornithopus* and to some extent *Biserrula* are particularly successful on acid sandy soils in Western Australia particularly, and in New South Wales and Victoria. The Perth Seed Bank has operated as an Australian collection in collaboration with researchers across southern Australia.

Many new cultivars of *Trifolium*, *Ornithopus* and *Biserrula* have been developed by Western Australian plant breeders and researchers since the collection was established in 1984. Most of these cultivars could not have been developed without the existence of the germplasm collection. Cultivar development has focused on adaptation to sandy, acid soils from high rainfall permanent pasture to low rainfall pasture/crop rotation systems. In the past 10 years, the following cultivars have been developed for use in Western Australia:

- Dalkeith and Izmir subterranean clovers (*Trifolium subterraneum*)
- Santorini, Yelbini and Charano yellow serradellas (*Ornithopus compressus*)
- Cadiz, Margurita and Erica French serradellas (*O. sativus*)
- Persian Prolific and Nitro Plus Persian clovers (*Trifolium resupinatum*)
- Prima gland clover (*T. glanduliferum*)
- Cefalu arrowleaf clover (*T. vesiculosum*)
- Portalu eastern star clover (*T. dasyurum*)
- Electra purple clover (*T. purpureum*).

Many of these cultivars have application in other southern Australian states. Consequently, the collection will continue to have strategic value in providing the raw material necessary for effective cultivar development.

Conservation value of most of the germplasm is high. More than 90 per cent of the germplasm is from collections made in the wild by Australian researchers and consequently unique in the world of *ex situ* seed banks. Less than 10 per cent of the germplasm has been sourced from other *ex situ* seed banks. Most of the germplasm is of high priority species, since Australian researchers were focusing on a limited range of priority species.

Current functions of the five centres—different practices and scope for rationalisation

Almost all the centres perform the standard seed bank functions of acquisition, documentation, storage, viability monitoring and regeneration, seed distribution, and information management. Centres vary in their level of involvement with other functions or operations, namely quarantine, collection, evaluation, research and communication. The different demands imposed by the nature of the collections determine the extent of the functions performed by the respective centres.

The following illustrates some of these differences in the nature and status of the collections:

- The Tamworth Seed Bank has the narrowest range of species in its collection; the collection is very diverse intraspecifically. This reflects the importance of wheat and barley in the Australian economy and the need to service intensive ongoing improvement in these crops. The centre has an emphasis on diversifying and understanding its genetic diversity base, and extensive seed distribution.
- The Horsham Seed Bank works very closely with, and responds primarily to the needs of, national crop improvement programs for a diverse range of pulse and oilseed crops, including development of commercialised lentil and chickpea varieties. An increasing emphasis is being placed on acquiring and utilising wild relatives. The centre has the closest direct working links of all the centres with researchers applying molecular approaches to plant breeding, and linking phenotypic and genotypic data.
- The Adelaide and Perth Seed Banks have been key players in the shifts in those states from sowing subterranean clover and annual medic dominated pastures to more diverse annual pastures. This has been in response to economic and sustainability challenges. Both centres have an increasing emphasis on acquiring land race, perennial and native species diversity for use in more sustainable southern pasture systems.
- The Biloela Seed Bank is unique among the centres in holding the most diverse range of species in its collection. This reflects the fact that it is the only centre focusing on collecting tropical germplasm. At Biloela, the accessions are maintained to international standards but regeneration and viability testing is no longer taking place.

Other differences in practices—historical, cultural or operational—are due to different curatorial or management philosophies and priorities, but also to the existing structure of the network of centres. There is a need for rationalisation through prioritisation, standardisation, harmonisation, and removal of duplication.

Other Australian germplasm collections

There are many smaller germplasm collections in Australia, in addition to those of the five major seed banks. Some of these collections are large, for example:

- the Canberra Seed Bank holding of soybean (*Glycine*), rice (*Oryza*), cotton (*Gossypium*), tobacco (*Nicotiana*) and sorghum (*Sorghum*) wild relatives accessions (approximately 3400 accessions, plus many accessions of the cultivated crop species *Glycine max* [more than 100] and *Oryza sativa* [365 accessions])
- the CSIRO Tree Seed Centre (Canberra) holding of 1200 species including *Eucalyptus*, *Acacia*, *Casuarina*, *Grevillea*, and *Melaleuca* and diverse other native tree and shrub species

- a University of Western Australia barley collection (11 000 lines of wild types, land races, varieties and breeding lines, plus 45 000 double haploid barley lines, growing annually by 5000 lines)
- a Western Australia Department of Agriculture lupin collection (around 4000 accessions).

There are a further number of small collections, which include the only germplasm collections of certain agricultural species held and conserved in the country. Many of these smaller collections are of horticultural species and often comprise living plants (especially tree species).

Another significant collection outside the five main ones is that of the Margot Forde Forage Germplasm Centre (Palmerston North, New Zealand), which holds the Australian genebank for temperate perennial grassland plants. The Centre holds about 70 000 seed samples of about 1000 species of herbaceous and shrubby temperate forage and grassland plants, mostly grasses and legumes.

There are also microbial collections in Australia that are significant for agricultural crops, including collections of *Rhizobium* (nitrogen-fixing mycorrhizae essential for many legume crops and pastures), fungi and microalgae.

DNA banking

Biotechnology now enables DNA (genes) to be identified, sequenced and characterised. Molecular plant breeding, genomics and phenomics research has resulted in tens of thousands of DNA samples being isolated and generated by researchers.

DNA banking is unlikely to replace conventional germplasm storage (as seeds). Its current primary value lies not in its use as an alternative to seed banking, but as a supplement to it; storing characterised DNA obviates the need to re-extract, and allows it to be readily accessible, saving time and resources.

DNA can be stored for long periods at either -20°C or -80°C . Australia has a single facility dedicated to DNA banking at the Australian Plant DNA Bank (Southern Cross University, Lismore, New South Wales). The facility holds plant DNA samples of a range of exotic and native species of relevance to food and agriculture. It has a total capacity of tens of millions of samples. It currently has 7455 accessions in its collection.

The global Svalbard seed vault

A global seed bank has been established at Svalbard in the Arctic Circle, an island 1000 km off northern Norway. The seed vault was established in February 2008, to 'provide insurance against both incremental and catastrophic loss of crop diversity held in traditional seed banks around the world'. It 'offers "fail-safe" protection for some of the most important natural resources of the world' (www.croptrust.org/main/arcticseedvault.php?itemid=211).

The vault currently holds over 640 000 accessions. Australia's first consignment, sent in early 2011, included 301 pea and 42 chickpea land race accessions originally imported to Australia many years ago. A number of the chickpea lines deposited in the vault are now judged to be very rare.

It is important to note that the vault is primarily a backup collection, and not a working seed bank.

Native species seed banks

The Australian states have a history of recognising the importance of native species conservation and management of native species, especially rare and endangered species. For example, work on these

is done at the Western Australia Department of Environment and Conservation seed bank and the King's Park Botanic Garden, both in Perth. The latter is also practising cryogenic tissue storage as a supplementary conservation strategy for critically endangered species.

New South Wales also funded the establishment of a native species seed bank at Mt Annan Botanic Gardens, near Sydney. This facility recently received a \$15 million infrastructure boost in the 2010 state budget.

Other states received a boost to their native germplasm conservation and management efforts through the United Kingdom's Millennium Seed Bank project, funded by the UK lottery and based at Kew Gardens, Wakehurst Place (Sussex, United Kingdom). The Millennium Seed Bank project is a Global Strategy for Conservation of native species.

The project aimed to conserve and manage 10 per cent of the world's native species flora (24 200 species) by 2010; the target was reached in October 2009. Germplasm is conserved in a nuclear bomb-proof seed bank facility at Wakehurst Place. The seed bank enters into access and benefit agreements with countries that lodge germplasm at the seed bank.

Australia is one of 18 partner countries. The Australian native species target for the Millennium Seed Bank was 25 per cent of the native species flora (over 5000 species) to be placed in the seed bank by 2010 (www.kew.org/science-conservation/conservation-climate-change/millennium-seed-bank/projects-partners/partner-regions/australia/index.htm).

The Australian partners include:

- Victoria (Royal Botanic Gardens)
- South Australia (Adelaide Botanic Gardens)
- Tasmania (Royal Botanic Gardens)
- Northern Territory (Department of Natural Resources, Environment and the Arts).

The Millennium Seed Bank funding agreement with Queensland was with Seeds for Life Queensland, involving Brisbane Botanic Gardens (which previously did not have a native-species seed bank), Greening Australia, the Queensland Herbarium and university partners; together these organisations are known as the Q-Seed Partnership.

Australian partners formed a national seed bank network, Australian Seed Conservation and Research to harmonise activities across the project partners. The Australian Seed Conservation and Research network aims to ensure that the teams in each region are not duplicating collections. It also aims to ensure a program of collaboration between research groups from each state. Millennium Seed Bank funding for the network was due to terminate in 2009. At that time, 17 institutions and organisations were in the process of initiating a new partnership, the Australian Seed Bank (www.anbg.gov.au/anpc/apc/17-4_north.html). The organisations involved then consisted of Australian Seed Conservation and Research members, the Australian National Botanic Gardens and Greening Australia's Florabank. This new partnership recognises the need not only to develop a nationally coordinated approach to seed banking and research, but also to improve integration of conservation seed banking with landscape restoration activities.

During the review of plant genetic resources for food and agriculture in 2007, it was recognised that native species conservation is also important for agriculture and so possible synergies were investigated. The benefits of cooperative arrangements in national frameworks for plant genetic resources for food and agriculture and those for native species include the major issue of addressing,

clarifying and ensuring access arrangements for native species germplasm of relevance to food and agriculture. The Commonwealth's access and benefit sharing legislation is part of the *Environment Protection and Biodiversity Conservation Act 1999*. Most states now have legislated access and benefit-sharing regimes for native biodiversity, and access issues both within and between states will become increasingly complex as native species germplasm is increasingly sought and used for agricultural plant breeding.

Current status of *in situ* conservation

In situ conservation is important not only because the Australian flora contains many species that are close relatives of agriculturally important food and other crops, but also because any gene from a native species could potentially have agricultural significance in the future (for example, a drought tolerant gene from a native desert species introduced into a crop species). Although only two native Australian species are current food crops (*Macadamia integrifolia* and *M. tetraphylla*—'macadamia nuts'), many food and other important crop or forage species have relatives represented in genera of Australian native flora, or very closely related genera. These Australian genera (crop/forage relative in parentheses) include:

- *Sorghum* (grain sorghum, milo)
- *Glycine* (soybean)
- *Oryza* (rice)
- *Pennisetum* (pearl millet)
- *Vigna* (beans and cowpeas)
- *Cajanus* (pigeon pea)
- *Citrus* (full range of citrus fruits)
- *Solanum* (potato)
- *Gossypium* (cotton)
- *Nicotiana* (tobacco)
- *Andropogon* (beard grass)
- *Panicum* (switchgrass, common millet)
- *Poa* (bluegrass)
- *Festuca* (fescue fodders)
- *Atriplex* (saltbushes).

The *in situ* conservation status of these specific indigenous related wild plant genera has not been reviewed in detail, but only two species (*Cajanus mareebensis* and *Macadamia janseni*) of the genera noted above are known to be endangered, and none are 'critically endangered'. A greater number of native species are listed as 'vulnerable (www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=flora). These include:

- *Atriplex infrequens*

- *Glycine letrobeana*
- *Macadamia integrifolia*, *M. tetraphylla*, *M. ternifolia*
- *Poa sallacustris*
- *Solanum carduiforme*, *S. dulanianum*, *S. karkense*.

The *in situ* conservation status of most species of closely related wild plant genera is therefore not critical at this time. The *in situ* conservation status of all other native species is extremely variable, with 47 extinct, 113 critically endangered, 531 endangered and 651 vulnerable species listed on the Department of Sustainability, Environment, Water, Population and Communities website (viewed 2 June 2011) in an estimated total native Australian plant species total of more than 20 000.

Functions of national genetic resources centres

Seed banks are integral in providing and conserving the plant diversity needed for food. These genetic resources are the seeds for Australian crops, vegetables, fruits, forages, feed and pastures.

The storage of genetic resources long-term is primarily a conservation function; the collection should be determined on 'accession-worthy' criteria. Ideally, the species should cover the full range of crop, forage and pasture species, and their relatives, that are currently or potentially agriculturally important in Australia. This should include species of natural resource management value to agricultural systems, as well as native and non-native wild species.

Unless determined to be of no current or potential future value, accessions that are already in long-term storage should be kept even if known to be held overseas, because of the costs of importing germplasm. However, these accessions may be given a lower priority for viability monitoring and regeneration than these accessions in demand.

Under a national framework, centres could also offer any user storage of germplasm material that it would not otherwise store, as a fully cost-recoverable service. An example of this is the storage and seed increase by the Tamworth Seed Bank of CIMMYT (International Maize and Wheat Improvement Centre) material.

Information management should be standardised. This includes for example, whether evaluation data of breeders belong in a seed bank database or not. Evaluation and other data in the accession database could clearly help researchers, pre-breeders and breeders to target more precisely the germplasm of use to them. Supplying such data is also a requirement under the treaty.

A national system also needs information management and development of an online web-based portal for collection databases and a common platform for managing and searching databases across diverse crops and species. There is a general consensus about how key functions and practices should be performed and that the information held on accessions needs to be improved. There is a need to review and prioritise what collections are held at species and intraspecific levels. The Germplasm Resource Information Network database system (www.ars-grin.gov), a global plant genetic resources web server providing information on plant germplasm (used by the Global Crop Diversity Trust in collaboration with United States Department of Agriculture – Agricultural Research Service), could be an appropriate system.

The handling of material transfer agreements needs to be standardised, and a core germplasm collection developed. There is general agreement that the centres need to have a national identity

and function as a national system, and that Australia needs to present a single national system to the international community.

Who uses and benefits from the plant genetic resources in Australia?

Currently, five state governments (Queensland, New South Wales, South Australia, Victoria and Western Australia) and the GRDC directly contribute to funding of plant genetic resources centres in Australia.

Universities, research institutions and industry users other than the grains industry also benefit from genetic resource collections and their use in plant improvement. In this context, plant improvement is often intentionally directed at improving pastures or feed.

Breeding for more sustainable pastures, or plant improvement aimed at crops, often indirectly benefits the animal industries; animals are fed grains and other food crops for finishing or as feed supplements in times of drought. Indeed, some industries (such as pigs and poultry) depend on feed, including grain, and manufactured feed products, the quality of which can be directly influenced by plant improvement through plant breeding. The beef, dairy, poultry, pig and wool industries all benefit from plant breeding and pasture improvement research, which, in turn, require seeds from seed banks.

Use of the plant genetic resources centres

Seven years of data to mid-2006 or the end of 2006 were analysed to examine the use of plant genetic resources centres. The analysis aimed to distinguish public institution and agency users from private users and overseas from domestic use, and to identify use by the current contributors to seed bank funding and by others.

Seed sample distributions to users were therefore split into overseas and Australian distributions. Within the overseas category, users were put into one of the following categories: overseas agricultural institute, other overseas institute (including universities), overseas seed bank, or overseas private industry. Within the domestic category, users were put into one of the following categories: state agency, Australian university, CSIRO, other Australian research institution, Australian seed bank, non-governmental organisation, or Australian private industry.

Over 14 000 accessions are distributed annually to Australian users. Approximately 3000 accessions are requested by overseas users annually. From the local plant genetic resources users, state agricultural agencies constitute the biggest user category (45 per cent of total items distributed in Australia), followed by universities (23 per cent), private (commercial) users (18 per cent) and CSIRO (12 per cent).

3 Australian reviews of plant genetic resources for food and agriculture

During 2006–07, there was extensive consultation on plant genetic resources issues with governments, plant genetic resources centres and others including curators, industry, plant breeders, and researchers. A progress report was prepared and guiding principles were developed, as well as producing a number of working documents and undertaking analyses.

After detailed consideration of a range of options, the National Genetic Resources Centre steering committee decided that a two-node model was the preferred option for the centre. The crops collections would be consolidated at the Horsham Seed Bank and the pastures collections at the Adelaide Seed Bank, the two most modern and spacious existing facilities. This would reduce costs, provide improved services and allow more efficient and innovative management.

The proposed National Genetic Resources Centre would be established under a memorandum of understanding or by intergovernmental agreement.

Establishment of the centre would achieve national leadership, information management, structural, staffing, and operational reforms. The structural reform would also enable operational efficiencies, with significant implications for ongoing costs. Funding reforms would also be needed.

The need for a national centre

Primary Industries ministers agreed in April 2006 that a National Genetic Resources Centre be established involving the Australian Government and states, to implement change, place plant genetic resources on a more secure footing and achieve improvements and efficiencies.

The steering committee for the proposed National Genetic Resources Centre noted that:

- plant genetic resources conservation and management operations need reforming, prioritising, rationalising and harmonising
- a national informatics platform and information management system is needed
- priorities need to be set for strategic acquisition of new germplasm and for management of current holdings.
- establishing a National Genetic Resources Centre would also help Australia to implement its obligations as a signatory to the International Treaty on Plant Genetic Resources for Food and Agriculture. For example, Australia is now obliged to comply with the treaty's Standard Material Transfer Agreement in international seed transfers. The National Genetic Resources Centre's 'national collection' could be placed in the International Treaty on Plant Genetic Resources for Food and Agriculture's Multilateral System for collections.

The National Genetic Resources Centre steering committee agreed on the governance, structure and function of a national centre, and has identified major reforms.

Toward a two-node National Genetic Resources Centre

In order to establish an effective national centre, the National Genetic Resources Centre steering committee recommended the following changes to the Primary Industries Standing Committee.

- **Increased focus on core business**
The core business of the National Genetic Resources Centre should be the conservation, distribution, documentation and strategic acquisition of genetic resources (mainly seeds), and associated information management, for research providers. Additional activities such as collection, characterisation, evaluation and utilisation of genetic material should be pursued as appropriate. Operational arrangements and acquisition priorities, and the way these are funded, should be rationalised.
- **Governance reform**
All resources should be under the control of a representative national board, comprising state and Australian Government and research and development corporations representatives. The National Genetic Resources Centre should be an unincorporated joint venture, underpinned by an intergovernmental memorandum of understanding or other agreement.
- **Structural reform**
There are economies of scale and operational efficiencies to be gained from rationalising from five to two centres. Of the existing centres, the Adelaide and Horsham facilities are the most modern and have the largest cold storage capacities among existing centres. They are therefore the most likely to be suitable for upgrading by expanding their storage capacity to accommodate the other collections. Both the Adelaide and Horsham seed banks have access to field, glasshouse and other plant culture facilities and are adjacent to the Department of Agriculture, Fisheries and Forestry—Biosecurity accredited on-site post-entry quarantine facilities.
- **Staffing reforms**
Leadership, operational management, administration, policy, and information management could be undertaken by a new dedicated national office team, enabling more focused and more efficient coverage of these diverse functions.
- **Information management reforms**
The information management systems used in the five existing centres are currently diverse. Online user access to holdings and associated information is not available for some collections. Seed movement systems and inventories differ in their methods, and there is no agreed view on how to manage information or what information should be collected and prioritised. There should be a single online, user-friendly, web-based portal to access the National Genetic Resources Centre collection database(s) and make germplasm requests.

National Genetic Resources Centre information management system should be fully linked with other international and national plant genetic resources information management systems. It could be linked to and compatible with the Atlas of Living Australia, a national informatics capability developed with Australian Government National Collaborative Research Infrastructure Strategy funding.

A National Genetic Resources Centre policy needs to be developed to specify the information held in the National Genetic Resources centre information management system and inventories. These reforms are essential to improve the usefulness of the collection to plant pre-breeders and breeders. The system should also be able to provide easily accessible information on accession transfers to the International Treaty on Plant Genetic Resources for Food and Agriculture.

- **Quarantine arrangements**

Quarantine services should be outsourced to the most appropriate, cost-efficient and professional facility, through an MoU or contract with two or more quarantine service-providers (these could include facilities at the South Australian Research and Development Institute, Adelaide, the Queensland Department of Primary Industries and Fisheries, Eagle Farm, and the Department of Primary Industries, Horsham, Victoria).

What has happened since 2007?

The Australian, state and territory governments have periodically considered establishing a national system for managing Australia's agricultural plant genetic resources. This is currently being progressed by the Primary Industries Ministerial Council and Primary Industries Steering Committee.

The Primary Industries Steering Committee agreed to a broad approach to funding the National Genetic Resources Centre and referred the issue of nationally managing Australia's agricultural plant genetic resources to Primary Industries Ministerial Council, for consideration within the context of the National Research, Development and Extension Framework. Plans and timeframes for establishing, funding and maintaining a two-node National Genetic Resources Centre are being developed. The Grains Research and development Corporation has taken the lead in consolidating the cereals collections at the Horsham seed bank and discussions are continuing among relevant stakeholders for suitable arrangements for the remaining pastures collections.

4 Summary assessment—toward a plant genetic resources framework for Australia

Seed banks are integral in providing and conserving the plant diversity needed for Australia's food. They sustain ongoing efforts to improve and adapt crops and pastures. The establishment of an Australian centre for plant genetic resources for food and agriculture in the form of linked seed banks would support both plant improvement strategies and access to seed of alternative crops or pastures.

Furthermore, Australia is facing significant challenges—climate change, drought, increased salinity and soil acidity. Seed banks will help meet these challenges. Improving crops and pastures allows Australia to maintain or increase agricultural productivity and make Australian agriculture more competitive in international markets.

Changing food preferences among the populations of major emerging economies (such as China and India) may lead to diversion of some human food supplies to animal feed, or the use of agricultural land to produce feed instead of crops for direct human consumption. Australia is in a good position to capitalise by introducing new varieties into its production systems to respond to higher demand for animal feeds. However, this will require access to germplasm to develop suitable new varieties.

Australia's plant genetic resources for food and agriculture need adequate conservation and management to maintain its plant breeding capability in the mid to long term, and the ability to maintain or increase productivity and improve agricultural sustainability.

Acronyms and initialisms

CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Centre collection in Mexico (Centro Internacional de Mejoramiento de Maíz y Trigo)
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DNA	Deoxyribonucleic acid
FAO	Food and Agriculture Organization
GRDC	Grains Research and Development Corporation

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