Chapter 8

Curating seeds and other genetic resources for ethnobiology

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INTRODUCTION

The term genetic resources, or germplasm, refers to propagating material of plants and animals, including seeds, pollen, vegetative propagules and animal semen. It can also encompass whole plants and animals, in their role as reservoirs of genetic material. Germplasm forms the basis of plant and animal reproduction, and thus of the conservation and generation of genetic diversity. Although germplasm conservation is usually thought of as a tool for making the diversity of crops and their wild relatives available to plant breeders, it is now recognised as having equally important roles in the reintroduction of traditional crops to farm fields or gardens, or of wild species to wild habitats.

In theory, germplasm and ethnobiology should be closely interlinked. Plant germplasm, for example, has two central attributes that are relevant to ethnobiology: use, and threatened conservation status. A significant proportion of all plants fall directly within the 'useful plants' brief of the ethnobotanist. Karl Hammer et al. (2003: 242) have estimated that about 122,000 of the world's approximately 300,000 known higher plant species are useful as crops or crop wild relatives, and there are probably tens of thousands of species that humans can use for other purposes. The vulnerable status of a significant proportion of plants is not disputed: between a quarter and a third of all plant species are threatened by extinction, and massive losses of agricultural biodiversity have occurred over the past 50 years. For ethnobiology, a discipline much concerned with sustainable development, germplasm conservation is clearly central. Yet, the three most-used ethnobotany manuals barely mention germplasm or genebanks, and the same is true of almost all ethnobotanical papers (Martin, 1995; Alexiades, 1996; Anderson et al., 2011).

In this chapter we have two aims. The first is to orientate ethnobiologists in the variety of techniques used to preserve germplasm. Although it is now widely accepted that an approach that uses and integrates all of these will be most successful in preserving biodiversity, publications still tend to cover just one technique. Here, we touch on all, although giving most attention to seed genebanks. Second, we put forward some suggestions on how the ethnobiologist can integrate genebank collections into their research and practice. We expect these will also be useful to institutional germplasm curators seeking to take a more ethnobotanical approach to collections. In this chapter, we give details of storage practices for plant and animal germplasm at the United States' National Center for Genetic Resources Preservation, but in general we avoid giving too much detail on collecting and curation, as these topics are well covered in guides, many available online.

CONSERVING GERMPLASM: CHANGING METHODS AND CONCEPTS

Beginnings

Techniques for maintaining germplasm are widely used in traditional agriculture, and undoubtedly date back to the beginnings of farming (Brush, 2004). The concept of separate, permanent collections of germplasm is much more recent, dating to the development of classical plant breeding at the end of the 19th century. The emphasis shifted from botanic gardens, which typically preserved representative species as one or a few living plants, to genebanks that preserved as wide a range of populations as possible, typically as seeds. The genebank both protected genetic diversity and made it available on request to the plant breeder. Early examples of genebanks include the Bureau of Applied Botany in St. Petersburg, founded in 1894 and collecting on a large-scale since 1908 (now the N. I. Vavilov Research Institute of Plant Industry), and the United States' Office of Foreign Seed and Plant Introduction founded in 1898 (Loskutov, 1999; Pistorious, 1997). By contrast, the development and use of national gene banks for livestock is relatively new. The US Department of Agriculture was only given a remit to preserve animal germplasm in 1990 (Blackburn, 2009).

Expansion and standardisation

The 1970s saw two major advances in plant germplasm. The International Board for Plant Genetic Resources (later IPGRI, now Bioversity International) was founded in 1974 and acted as a catalyst for the formation of many genebanks worldwide, as well as establishing common standards for collection management. At the same time, experiments showed that storage at –18°C (–0.4°F) or below meant that the seeds of many species could be stored for decades or centuries. This reduced the need for frequent regeneration of seed, with its associated risk of hybridisation and other changes to preserved diversity.

For much of the 20th century, efforts to preserve genetic diversity in plants were based on the provision of a resource for plant breeders. Plant and animal germplasm was collected worldwide and stored in genebanks in locations that made it easily accessible to researchers and breeders. This effort was successful, with the collection of hundreds of thousands of accessions, and their use in work such as the Green Revolution of the 1960s, which massively increased the yield of wheat, rice and maize. International and national genebanks continue to fulfil this role, not only in anticipation of climatic changes, natural disasters, or new pathogens that could lead to germplasm extinction, but also to safeguard resources for future uses in new areas of agriculture, such as bioenergy, new food sources from plants, or the development of medicinal plants. As cultivated crops and animals are threatened with pests and diseases that could damage or even lead to the extinction of cultivars or lines, these collections take on even greater importance. Plant and animal breeders look to these biocultural collections to provide new resistant cultivars, lines or genes, and need access to high degrees of genetic variation to assure food security along with other agricultural products (Jackson et al., 2007).

Community participation

Towards the end of the 20th century, there was increasing awareness among agronomists that farmers themselves continued to play a major role in the maintenance of traditional landraces of crops and animals, despite all the pressures on their preservation. Studies showed that farmers continued to grow landraces of crops alongside newly introduced cultivars, and that these were continuing to evolve under the influence of changing environment and farmer selection (Brush, 2004). At the same time, it became clear that national and international genebanks were not easily accessible to farmers, either those desiring to innovate with new materials or those wishing to reintroduce crops and animals formerly cultivated but now lost from their communities. Notably, Gary Nabhan's *Enduring Seeds* (1989) drew attention to the vulnerability of native crops in North America, and the importance of their continued cultivation in the preservation of Native American cultures. This implied that preserved germplasm should be distributed not only to plant breeders but also to farmers and gardeners, and that this distribution would benefit not only food security but also the conservation of traditional cultures. As discussed late in this chapter, new forms of genebank evolved that were based on community collaborations.

Wild plants

Most genebanks focus on crops and domesticated animals, and their wild relatives, and thus support agriculture. Conservation of the remaining wild species — some 200,000 in the case of flowering plants — usually depends on conservation of their habitats or on their cultivation in botanic gardens. The establishment of the Millennium Seed Bank by the Royal Botanic Gardens, Kew in 2000, which stores the seeds of wild plants rather than crops, has greatly increased the proportion of wild plant species housed in genebanks. Partnerships in over 50 countries have led to over 40,000 species (over 10% of flowering plant species) being collected and stored. Seedbank preservation is now one of the recognised strategies of wild plant conservation.

Animals

Given the diverse nature of preserving animal genetic diversity and the variable set of needs in different countries, there have been difficulties in creating standardised protocols for preserving animal germplasm. To date, animal genebanks are best developed in the USA (National Center for Genetic Resources Preservation, National Animal Germplasm Program), Canada (Canadian Animal Genetic Resources Program), the Netherlands (Centre for Genetic Resources (CGN)) and France.

WHERE IS GERMPLASM CONSERVED?

Introduction: *in situ* and *ex situ* conservation

In situ conservation is the maintenance of germplasm in its original habitat; in farmers' fields in the case of domesticated animals and plants, or in wild habitats in the case of wild plants (in practice the distinction between these habitat types is blurred). In *ex situ* conservation, the plant or animal germplasm is maintained elsewhere. Both forms of conservation have their advantages. During *in situ* conservation, the plants or animals will continue to evolve, for example in response to climate change, generating new diversity. The germplasm is easily made available to local users through seed sale or exchange or through community genebanks. The preservation of traditional agricultural techniques, which are often necessary for the survival of traditional crop landraces, may lead to strengthened cultural heritage. *In situ* conservation efforts aimed at specific wild plants are likely to involve landscape conservation with wider benefits for biodiversity. In contrast, *ex situ* conservation will capture snapshots of germplasm at specific points in time, potentially saving diversity that is later lost. Seed longevity in *ex situ* storage can be highly predictable. *Ex situ* conservation of plants uses three techniques: growing plants in field genebanks, freezing seeds, and *in vitro* conservation, in which plant tissues such as buds, meristems and embryos are cultured in the laboratory.

Storage as frozen seeds is by far the least labour-intensive and cheapest method of *ex situ* preservation, and accounts for the great majority of accessions in genebanks. There, are however, two obstacles to the preservation of all plant species as frozen seeds. First, not all seeds can be frozen.

Part of the treatment before freezing is to dry seeds, otherwise ice will form on freezing and the seed will be killed. However, the seeds of many species are desiccation-intolerant and will be killed during the drying process; these are known as recalcitrant seeds. By contrast, seeds that survive drying, and which can therefore be frozen, are known as orthodox seeds. Recalcitrant seeds are most common in wetter habitats (Tweddle et al., 2003). Second, some plants reproduce exclusively by vegetative means, or are clones that can only be preserved by vegetative propagation. In these cases, field genebanks and *in vitro* conservation must be used. Field conservation, through the cultivation of plants, is relatively simple to implement is but labour-intensive and leaves the germplasm vulnerable to disease. *In vitro* techniques require good laboratory facilities (González-Arno et al., 2008).

Animal germplasm is preserved through cryopreservation (Figure 1) of semen as the primary mechanism, followed by embryo collections at a smaller rate and scale. For an example storage protocol for animal germplasm, see Box 'Storage protocols for animals at the National Center for Genetic Resources Preservation (NCGRP)'. Living collections are also important (Tempelman et al., 2007).

UNITED STATES NATIONAL PLANT GERMPLASM SYSTEM

This is a network of over 20 regional sites including Plant Introduction Stations, field sites, programmes, and centres curating individual crops and maintaining active collections. Examples include the Plant Introduction Station in Ames, Iowa, which has responsibility for over 20,000 collections of corn (*Zea mays*) along with other crops that grow well in that area. The Plant Introduction Station in Griffin, Georgia, has responsibility for the sorghum collection; wheat is maintained in Aberdeen, Indiana.

The National Center for Genetic Resources Preservation (NCGRP) has a mission 'to acquire, evaluate, preserve, and provide a national collection of genetic resources to secure the biological diversity that underpins a sustainable US agricultural economy through diligent stewardship, research, and communication.' It is one of the largest genebanks in the world, currently safeguarding over 875,000 plant collections and 652,295 animal collections, most with agricultural emphasis. This number represents 7,474 different plant species of 1,274 genera, as well as 13 agricultural animal species and over 130 breeds. These accessions are freely distributed to any qualified research scientist in the world. The centre is the long-term storage facility for the base collection of the United States' National Plant Germplasm System (NPGS) as well as the base collection for the United States' Animal Germplasm Program.

Seeds or vegetative plant parts are sent to NCGRP from field sites for duplicate backup. Crop-specific curators manage new collections and the regeneration of existing collections. Each agricultural crop (sometimes a group of similar crops) and wild relative species has a curator responsible for its collection and regeneration. The curator assigned to a crop or group of crops and wild relatives usually sets the criteria by which seeds or propagules are organised in long-term storage.

Requests for crop material can be submitted through the Genetic Resource Information Network (GRIN) website, first by searching the database, then by using the link to 'Request this Germplasm'. More specific information about different crops can be obtained from individual curators via www.ars-grin.gov/npgs/holdings.html by clicking on a geographical location of interest.

Unlike plants, all of the United States' frozen animal germplasm is housed within the NCGRP. The National Animal Germplasm Program maintains germplasm from major, minor and rare animal breeds of agricultural importance. In addition, it facilitates the actions of livestock species committees that are comprised of the United States Department of Agriculture's (USDA) Agricultural Research Service, university and industry representatives.

See also Box 'Storage protocols for seeds at the National Center for Genetic Resources Preservation (NCGRP)'.

Ex situ conservation: seed and tissue collections

The Food and Agriculture Organisation of the United Nations (FAO) estimates that there are some 1,750 genebanks, holding 7.4 million accessions. About 25–30% of these are distinct accessions, the remainder being duplicates (FAO, 2010). About 130 genebanks hold more than 10,000 accessions; some major genebanks are listed in Table 1. By far the largest collection is that held in the various institutes of the Consultative Group on International Agricultural Research (CGIAR), including the International Rice Research Institute (IRRI), the International Maize and Wheat Improvement Center (CIMMYT), and the International Potato Center (CIP). It is common for large genebanks to be composed of such regional centres, which allow a wide range of plants to be grown in appropriate environmental conditions.

Genebanks do more than store germplasm. Two essential aspects of genebank research are into storage and germination. Seeds must be assessed to see if they are orthodox or recalcitrant, or intermediate, as this will determine the technique used to store them (Gold & Hay, 2008). Germination presents major challenges; for example, the discovery of smoke-stimulated germination as late as the mid-1990s has enabled many South African plants and Australian plants to be propagated for the first time (Staden et al., 2008). Genebanks also carry out routine testing of accessions before, at the start of, and at regular intervals during storage, to check propagation rates and viability. Germination of the seeds of wild plants may present major challenges; for example, the discovery of smoke-stimulated germination, as late as the mid-1990s, has enabled many South African plants and Australian plants to be propagated for the first time (Staden et al., 2008). Much information on seed storage behaviour and germination requirements is summarised in the Millennium Seed Bank's online Seed Information Database.

Most seed accessions in genebanks are relatively small: the preferred size for a base collection is usually 1,500–2,000 seeds; additional seed allows for distribution to users. For experimental and breeding work, small numbers of seeds are adequate, but for landscape restoration, 2–7 kg or more

TABLE 1
Major plant genebanks

NAME, LOCATION	NUMBER OF ACCESSIONS	COVERAGE
CGIAR, various countries	750,000	Crops and wild relatives
National Plant Germplasm System, USA	536,000	Crops and wild relatives
Chinese Academy of Agricultural Sciences, China	351,000	Crops and wild relatives
National Bureau of Plant Genetic Resources, India	349,000	Crops and wild relatives
N.I. Vavilov Research Institute of Plant Industry (VIR), Russia	322,000	Crops and wild relatives
National Institute of Agrobiological Sciences, Japan	243,000	Crops and wild relatives
Leibniz Institute of Plant Genetics and Crop Plant Research, Germany	148,000	Crops and wild relatives
Plant Germplasm System, Canada	113,000	Crops and wild relatives
National Genetic Resources Platform, Brazil	107,000	Crops and wild relatives
Millennium Seed Bank, United Kingdom	60,000	Wild plants

of seed will be required per hectare. The need for large quantities of seed from seed banks is a major challenge for genebanks (Hardwick et al., 2011). It can be met by scaling up production, or by the creation of specialist seed banks such as that of the Utah Division of Wildlife Resources, which is able to store 340 tons of seed (Merritt & Dixon, 2011).

Ex situ conservation: field genebanks

Field genebanks are well suited to clonally reproduced plants that do not reproduce true from seed, and for plants whose seeds cannot be stored frozen. They are often used for trees, which require less maintenance than tuber or seed crops; for example, more than 250 accessions of almond trees are grown at Zaragoza in Spain, over 500 olive accessions are maintained in Marrakech, Morocco, and the National Fruit Collection at Brogdale Farm, United Kingdom, has over 3,500 cultivars and landraces. Living collections of vegetatively reproduced crops include the Centre for Pacific Crops and Trees in Fiji, which has more than 1,100 taro land races, and major field collections of potato and sweet potato (the latter grown in greenhouses) at the International Potato Centre (CIP) in Peru. Living collections are vulnerable to disease, and those at CIP and other institutes are usually also held as *in vitro* tissue cultures.

Because plant cultivation does not require expensive facilities, it lends itself well to community genebanks, and to networked genebanks in which plants are kept at a number of locations. For example, the United Kingdom's Plant Heritage organisation (formerly the National Council for the Conservation of Plants and Gardens) is a collective of 650 specialist collections of ornamental plants located in both private and institutional gardens. Another network of living collections, in this case worldwide and focusing on medicinal plants, is Sacred Seeds (see p. 353). In both cases, a central office shares guidance on best practice, enables links between gardens and raises public visibility.

Botanic gardens already cultivate 80,000 plant species and have great potential to act as field genebanks, because of the strength of horticultural skills possessed by their staff (Chapter 10). The founding of Botanic Gardens Conservation International in 1987, and the first Global Strategy for Plant Conservation (2002), led botanic gardens to take a more strategic approach to conservation. This is important because individual gardens have relatively little space, leading to highly incomplete representation of plant species and of infra-species variation. For example, of 1,002 tree species recorded as Critically Endangered, only 192 are in cultivation within botanic gardens (Oldfield, 2009). The genetic basis of introductions can be narrow; for example, the dawn redwood *Metasequoia glyptostroboides* grows in 187 gardens but these plantings are derived from the seeds of just three trees (Oldfield, 2009). The quality of collections management continues to be uneven in botanic gardens (Maunder et al., 2001; Blackmore et al., 2011), and does not always match progress made in this area in other forms of genebanking. Cultivation of wild plants in botanic gardens can also lead to populations that are maladapted for reintroduction into the wild (Enßlin et al., 2011), suggesting that closer integration of living collections with seed and tissue storage in genebanks is required.

In situ conservation

The impact of new varieties of crops on traditional farming became particularly noticeable in the 1960s as the Green Revolution took hold. It was thought that most traditional land races would be displaced by new cultivars, but research on farms (especially, but not only, those in marginal areas) in the 1980s found unexpectedly high survival rates of land races and showed that farmers maintained these alongside high-input, high-yielding modern varieties (Brush & Meng, 1998). It has been eloquently argued by Nazarea (2005) that crop diversity survives in the margins — in gardens, among enthusiasts — but it is now clear that it also survives globalisation in farmers' fields. Examples include potatoes in Peru (de Haan et al., 2010), manioc in Brazil (Emperaire & Peroni, 2007), trees in Indonesian forest gardens (Marjokorpi & Ruokolainen, 2003) and home gardens worldwide (Webb & Kabir, 2009).

There are many unresolved questions when considering how *in situ* conservation can best be sustained, but there are some successful cases of the premium marketing of traditional products, with a clearly identified area of origin (Bardsley, 2003). For example, emmer wheat (also known as farro, *Triticum dicoccum*) is grown in Tuscany and marketed throughout Europe under European Union certificates of Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI). Payments to farmers can sometimes be direct (Narloch et al., 2011). The mechanisms of farmer selection and of seed exchange among traditional farmers that lead to the survival and generation of crop diversity are still poorly understood, but research in this area is highly active, in part because of the vital role of seed exchange in food security (Pautasso et al., 2012).

While the concept of *in situ* conservation is relatively new for crops, it is much longer established for wild plants, at least in developed countries. Here, nature reserves date back to the early 20th century, and there is a well-established methodology for the maintenance of biodiversity-rich landscapes, albeit in the context of pressure from industrial agriculture, housing and infrastructure (Given, 1995; Hamilton & Hamilton, 2006). *In situ* conservation for the wild relatives of crops, however, has come later, as they fall between two conservation sectors: that focusing on crop biodiversity and that focusing on wild plants. A series of major projects funded by the World Bank in the 1990s has led to the establishment of protected areas and management tools, both documented at the Crop Wild Relatives Portal website. *In situ* conservation has a long history among indigenous peoples, for example in the form of sacred groves that also function to protect plants (Anderson et al., 2005).

The role of community genebanks

Community genebanks focus on providing crop varieties for immediate use by local growers; in general, they do not hold wild relatives, which are mainly of use in plant breeding programmes. There is usually no long-term or frozen storage; seeds are 'lent' out to farmers, who then return a larger quantity after the harvest. The genebank is therefore continuously replenished. The genebank can draw material from local grower networks and from institutional genebanks. Such genebanks have developed both in developing countries, such as Ethiopia (Bezabih, 2008), India (Arunachalam et al., 2006) and Nepal (Sthapit et al., 2005), and in developed countries, such as France (Enjalbert et al., 2011).

In the USA, two organisations for community seed exchange operate on a large scale. Native Seeds/SEARCH works in the south-west of the USA and north-west Mexico and has about 2,000 arid land crops growing on a central farm. Seed Savers Exchange works mainly in the mid-West of the USA and preserves over 25,000 varieties; these are both preserved on a central farm and exchanged between members, thus blending the attributes of a seed genebank with those of a community genebank. Seed is backed up at the USDA Seed Bank in Fort Collins, and at Svalbard Global Seed Vault in Norway. In the United Kingdom, the Heritage Seed Library preserves about 800 accessions of traditional vegetables for garden production, which are kept and grown in a central garden and in the gardens of volunteer 'seed guardians'. In the case of domesticated animals, organisations such as the Rare Breeds Survival Trust (in the UK) and the American Livestock Breeds Conservancy (USA) act as central coordination points for breeding efforts carried out by individual farmers.

STORAGE PROTOCOLS FOR SEEDS AT THE NATIONAL CENTRE FOR GENETIC RESOURCES PRESERVATION (NCGRP)

The ethnobiological collection at the NCGRP preserves plant seeds and propagules, and animal germplasm (Appendix 2). Full protocols for storage are found on the USDA Plant and Animal Genetic Resource Preservation Research Unit website. For further guidance on how to collect, store and process seeds, see the manuals listed in Table 2.

At the field sites, seeds are dried to ambient conditions and cleaned to remove empty seeds and chaff. A sample of seed from each accession is retained at the field site for regeneration, multiplication, distribution, characterisation and evaluation, and comprises an active collection. The active collections are stored at 10°C to -20°C. The United States' National Plant Germplasm System (NPGS) base collection contains all the inventories of each accession including the original sample and earlier regenerations.

One of the considerations of seed storage is whether seeds are classified as orthodox, recalcitrant, or intermediate according to their dehydration behaviour. Orthodox seeds can easily withstand freezing because they can survive desiccation to below 10% moisture content thanks to their accumulation of protective sugars and proteins. Recalcitrant seeds cannot tolerate desiccation to 10% moisture content. The viability of stored seeds is periodically monitored using standard germination assays. A fresh sample of seed is obtained if seed supply is too low or if the proportion of seeds that germinate decreases below about 60%. A fresh inventory usually contains between 1,500 and 3,000 seeds.

When seed samples are received at NCGRP, the following steps are taken to assure proper storage conditions. **1)** Seed is placed at 5°C until unpackaged, logged into the database and inventoried (which takes 1–5 days). **2)** Seed moisture content is adjusted at 5°C to 25% relative humidity by placing it in an equilibration room for 3–4 weeks. **3)** Seed may be temporarily stored at -18°C for up to 4 months awaiting an initial viability assessment using standard germination tests. **4)** Seed quality is assessed through germination tests that use 'The Association of Official Seed Analysts' rules as a guideline (AOSA, 2011). Germination procedures are specific to each species. Under most circumstances, four replications of 50 seeds are evaluated for initial germination and viability. For collections considered for storage in liquid nitrogen, two of the four replications are exposed to liquid nitrogen for 24 hours prior to germination. **5)** Germination data are entered into the Genetic Resource Information Network (GRIN). **6)** The seed sample is weighed to determine seed number. **7)** Seed is packaged in a heat-sealable aluminium foil laminate bag. **8)** The package is labelled with bar code and location labels. **9)** Data on seed weight, seed number and storage location are entered into GRIN. **10)** Packaged seed is placed into NCGRP's -20°C storage vault or liquid nitrogen for long-term storage (Figure 1).

Similar procedures are used by other genebanks. Seed at the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) is processed by cleaning seed samples of extraneous materials, drying seeds to 8–10% moisture content for medium-term storage and to 3–7% for long term storage. Subsamples of a crop variety should be tested for the proper moisture levels. Seed viability is tested after drying and poor quality samples are sent for regeneration. Dry seeds that are frequently distributed are packed in plastic bottles or aluminium screw cap cans and placed in storage. The base collections are stored at –20°C for long-term storage and at 4°C and 20–30% relative humidity for medium-term storage. For a discussion on containers for seed storage, see Manger et al. (2003).

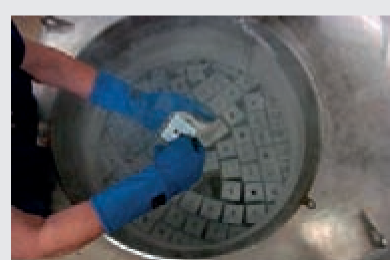

Figure 1. Cryopreservation is used for long-term storage at the National Center for Genetic Resources Preservation in Fort Collins, Colorado. Plant or animal germplasm is placed in a cryotank and submerged in liquid nitrogen or its vapour. © DR DAVID DIERIG.

Safeguarding germplasm

Genebanks are at risk from routine mishaps resulting from loss of electrical power, natural disasters and war, all having the potential to cause devastating loss of seeds and other forms of germplasm. Duplication of accessions is an effective precaution against the catastrophic failure of a genebank. For example, both the NCGRP and Kew's Millennium Seed Bank provide seed storage for other genebanks around the world, including government agencies, universities, botanical gardens, non-governmental organisations (NGOs) and Native American tribes. Access and Benefit Sharing Agreements (ABSA) with the depositor determine the conditions of storage and use of material. In some cases these are 'black box' agreements, in which ownership of the seed is retained by the depositor and the seed is not freely distributed or listed in the genebank's database. This service is typically provided free of charge, and all black-box-stored material is returned to the owner upon written request. The ultimate 'black box' is the Svalbard Global Seed Vault, which opened in Norway in 2008. This provides storage for about 700,000 accessions drawn from genebanks around the world.

INTELLECTUAL PROPERTY RIGHTS, LEGAL AND ETHICAL ISSUES FOR GENETIC RESOURCES

Dodds et al. (2007), Moore & Williams (2011) and Engels et al. (2011) offer useful reviews of these complex issues. This is a fast-moving field and up-to-date advice is essential. Until the 1980s, genetic resources were collected and distributed with few restrictions. The implementation of the Convention on Biological Diversity (CBD) in 1993 required prior informed consent and benefit-sharing agreements to be in place, in particular for transfers of biological material across national borders. Most international work that involves plant collecting takes place in accordance with agreements made under the provisions of the CBD; Moore and Williams (2011: 6) offer useful guidance on the exact procedures required.

The International Treaty on Plant Genetic Resources for Food and Agriculture, which came into force in 2004, is a system for the exchange of germplasm of major crop taxa between member states, within the framework of the CBD but without requiring new bilateral agreements for each case. For the 64 crops (and wild relatives) covered by the Treaty, genetic resources are made available under the terms of a standard Material Transfer Agreement. This allows use for research and breeding, with provision for benefit-sharing if the genetic resources are commercialised. The Treaty recognises the contribution of farmers and indigenous peoples' traditional knowledge of agricultural biodiversity.

Two other treaties are primarily concerned with plant breeders' rights (for commercial varieties) and will be of less relevance to ethnobotanists: the International Union for the Protection of New Varieties (UPOV), which focuses on plant varieties, and the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).

Much germplasm is held under bilateral agreements. Examples of cooperative agreements for plant germplasm at NCGRP include those for *Fraxinus* (ash) resources in the USA and Canada that are threatened by an invasive alien insect, the Emerald Ash Borer (EAB). The agreement facilitates the collection and storage of seed and helps to ensure that the genetic diversity of this important native tree is available for research to breed resistant trees, and for reintroduction of ash once adequate environmental control measures for EAB are developed. Another example concerns the storage of rare, sensitive, threatened and/or endangered plant species identified by the Center for Plant Conservation (CPC) as being in need of conservation. In addition, an agreement concerning the germination data, long-term storage, curation and viability testing of the United States' Bureau of Land Management

(BLM) Seeds of Success (SOS) National Collection provides for the long-term conservation storage of native plant genetic resources. In a final example, collaborations with the International Center for the Improvement of Maize and Wheat (CIMMYT) in Mexico, aid the conservation and regeneration of maize collections such as those found in the Hustecas region of Mexico, also monitoring populations of *Tripsacum* species in Mexico and regenerating or collecting seed from maize, *Tripsacum* and teosinte.

ETHNOBIOLOGY AND GERMPLASM

In the light of the issues and procedures surveyed in this chapter, here, we propose several guidelines for ethnobiologists.

Germplasm preservation is central to modern ethnobiology

Today, ethnobiology has changed from being primarily descriptive, or a tool for bioprospecting by external parties, to being a discipline that is applied to the betterment of the societies within which it works. One of the central threats to many communities is loss of diversity, both of domesticated and wild plants and animals. In the case of crop plants, ethnobotanists have played a major role in documenting and explaining crop diversity; examples include cassava in the Peruvian Amazon rainforest (Salick et al., 1997), sago palm in Indonesia (Ellen, 2006) and cider apples in the UK and USA (Reedy et al., 2009). Ethnobotanical fieldwork will often determine that crop diversity is being lost, but it is rare that this kind of fieldwork is integrated with or leads on to germplasm collection. Similarly, ethnobotanists often document significant decline in wild plant populations resulting from overharvesting or habitat destruction. Of course, both for crops and wild plants, the first response will be to support *in situ* conservation, for example through community management. However, an integrated approach to conservation, as advocated above, would lead to simultaneous *ex situ* conservation in a genebank, providing a safeguard in case *in situ* conservation fails.

Germplasm restoration is a powerful tool

The use of wild plant material held in genebanks is an integral part of species recovery, which focuses on individual taxa, and of restoration ecology, which focuses on revegetating degraded landscapes. It has obvious application to ethnobiology in the recovery of habitats and species recorded as once being in use, but now lost. The return of crop-plant germplasm from genebanks to source communities also has great potential, demonstrated in the successful work of Native Seeds/SEARCH, in returning local landraces to Native American farmers in the southwest USA, and through the flow of seeds from institutional genebanks to community genebanks.

Germplasm preservation and restoration are not easy

While we advocate an active role for ethnobiologists in germplasm collection and use, we must point out that special skills are required to overcome the potential obstacles. *Ex situ* conservation must take place within the appropriate ethical and legal framework, and must be based on a detailed assessment of the best way to preserve and propagate the plant. For major crops, these techniques may be well documented, but new research might be required for lesser-known plants. The collection of seed from wild plants requires a strategy to ensure that the seed collecting does not unnecessarily threaten the collected population (Way, 2003). Germplasm restoration also requires careful thought: is the plant culturally appropriate and being reintroduced to the right place? Could it be invasive or carrying disease? How will propagation and habitat management be achieved, particularly for wild plants?

Well-tested methodologies and advice are available

Fortunately, the questions raised above have already been researched, and the answers applied to real life cases. The widespread location of genebanks, and the availability of several methods manuals (Table 2), means that the ethnobiologist has easy access to advice and practical help. We strongly recommend that contact is made with nearby genebanks (and other germplasm projects) at an early stage if preservation or restoration is proposed, especially if a lesser-known or recalcitrant species is involved. Collection of orthodox seeds can (with careful guidance) be carried out by an ethnobotanist, but it may be preferable (and essential in the case of recalcitrant seeds or living plants) to invite a genebank team to visit the field area.

TABLE 2
Handbooks on germplasm

TOPIC	TITLE	REFERENCE
In situ preservation of useful plants and crops	*People, Plants, and Protected Areas*: *a Guide to In Situ Management*	Tuxill & Nabhan, 2001
In situ preservation of crop wild relatives	*Conserving Plant Genetic Diversity in Protected Areas*	Iriondo et al., 2008
	Crop Wild Relatives: a Manual of In Situ Conservation	Hunter & Heywood, 2011
All aspects of collecting plant germplasm	*Collecting Plant Genetic Diversity: Technical Guidelines*	Guarino et al., 1995; online as *Crop Genebank Knowledge Bases Wiki* website
	Collecting Plant Genetic Diversity: Technical Guidelines. 2011 update	Guarino et al., 2011
	ENSCONET Seed Collecting Manual for Wild Species	ENSCONET, 2009a
Seed collecting, preservation and propagation	*Seed Conservation: Turning Science into Practice*	Smith et al., 2003
Seed handling and storage	*Manual of Seed Handling in Genebanks*	Rao et al., 2006
	ENSCONET Seed Collecting Manual for Wild Species	ENSCONET, 2009b
Genebank management	*A Guide to Effective Management of Germplasm Collections*	Engels & Visser, 2003
Wild plant collecting and storage	*Ex situ Plant Conservation: Supporting Species Survival in the Wild*	Guerrant et al., 2004
Plant reintroduction and restoration ecology	*A Handbook for Botanic Gardens on the Reintroduction of Plants to the Wild*	Akeroyd & Wyse Jackson, 1995
	Restoring Diversity: Strategies for Reintroduction of Endangered Plants	Falk et al., 1996
	Restoring Disturbed Landscapes: Putting Principles into Practice	Tongway & Ludwig, 2010
	Restoring Tropical Forests: a Practical Guide	Elliott et al., 2013

PROJECT MGU: THE USEFUL PLANTS PROJECT AT THE MILLENNIUM SEED BANK (MSB)

TIZIANA ULIAN

The origins of the Millennium Seed Bank (MSB) lie in research into seed storage and germination carried out at the Royal Botanic Gardens, Kew from the 1960s onwards. In 2000, a purpose-built genebank was opened at Kew's second garden, at Wakehurst Place (Sussex, England) and collecting activities greatly increased in scale. The MSB now collaborates with 170 institutions in more than 50 countries, with the resulting seed collections being stored both in the country of collection and in the MSB. Access and benefit-sharing agreements are in place with each partner. The MSB strongly emphasises capacity-building in partner countries, including extensive training, and provides advice on the construction of new genebanks.

The focus of the MSB is on the seeds of wild plant species, many of which are used by local communities. The Useful Plants Project works with local communities in Botswana, Kenya, Mali, Mexico and South Africa through the Millennium Seed Bank Partnership. The first stage is for the communities to identify those plants of the greatest use and lowest availability, as well as obstacles to their use such as difficulty in propagation. The project then assists with the collection and *ex situ* storage of seeds in local and national genebanks, with training and enhancing facilities in local communities, with the development of propagation protocols, and with *in situ* conservation (Figures 2 and 3). Target species have included the baobab tree (*Adansonia digitata*), the sausage tree (*Kigelia africana*), the mongongo tree (*Schinziophyton rautanenii*) and the morma bean (*Tylosema esculentum*) in Africa, and the Mexican oregano (*Lippia graveolens*) and xoconochtli (*Stenocereus stellatus*).

LEFT **Figure 2.** Community nursery enhanced through the Useful Plants Project in Tharaka, Kenya. © TIZIANA ULIAN.

RIGHT **Figure 3.** Four-year-old plant of ngálăma (*Anogeissus leiocarpus*) planted in the community plot in Kougue, Mali. It is one of the plants used to make bògòlanfini, a traditional Malian mudcloth. It is also used as a human and livestock anthelmintic for treating worms, and for treatment of protozoan diseases in animals. © MOCTAR SACANDE.

Bear in mind that establishing a new germplasm repository is a major undertaking that will require significant follow-up. If starting a new genebank, or *in situ* conservation project, we strongly recommend also depositing duplicate collections in a well-established genebank that can guarantee long-term storage.

Collecting animal germplasm in remote locations necessitates the need for portable lab equipment (a microscope, battery-operated spectrometers and liquid nitrogen) and either freezing samples in the field or arranging for the shipment of perishable samples to a location where they can be cryopreserved.

Germplasm preservation should be an outcome of community consultation

The traditional approach to germplasm collection has been long-distance journeys during which plant seed is collected from the wild and from farmers from several locations each day. This technique has been highly successful in rapidly building up genebanks for crops and their wild relatives, but naturally results in little exchange of information between collectors and communities. By contrast, ethnobiologists are much more likely than traditional germplasm collectors to study an area long-term and to develop long-term relationships with the community that hosts them. This means that priorities for germplasm preservation or restoration will arise out of community discussion, facilitated as need be by the ethnobiologist. In addition to meeting the legal requirements outlined above, transfer of germplasm material (and related traditional knowledge) must meet the ethical standards of ethnobiology (Chapter 1). Community involvement is as important for *in situ* conservation; success requires that conservation practices are embedded in local communities (de Boef et al., 2012).

Where the initiative for germplasm conservation comes from an external genebank, then it is necessary to establish a working relationship with indigenous groups before any collection takes place. In some instances this process can take several years.

Ethnobiology has much to contribute to germplasm research and preservation

Ethnobiologists have much to offer germplasm collection programmes. They bring skills in prioritising species for use and conservation through quantitative field research methods (Gold & McBurney, 2012). For example, Albuquerque et al. (2009) assessed the conservation priorities of 166 useful plant species in the caatinga vegetation of north-eastern Brazil. High priority was allocated to plants that had multiple uses but were rare in home gardens or in the wild. A similar approach is taken by the Useful Plants Project at the Millennium Seed Bank (see Box 'The Useful Plants Project at the Millennium Seed Bank').

Ethnobiologists bring more than a utilitarian perspective; they can also bring their role as 'trained experts in gathering, filtering, and managing local knowledge, and in fostering engagement with local communities. Ethnobotanists can ensure that issues, such as prior informed consent, respectful use of local community members' time and resources, data ownership and the sharing of results and benefits with local communities, are managed properly and in accordance with agreements such as the Convention on Biological Diversity.' (Saslis-Lagoudakis & Clarke, 2012).

GERMPLASM AND INDIGENOUS KNOWLEDGE

Indigenous knowledge of relevant collections has not been fully appreciated, or captured in the data management systems of modern genebanks. The traditional methods of local farmers are as important as the methods used by modern, mechanised agriculture, although there have been few efforts to preserve this knowledge. Preservation of cultural information supports and complements the genetic, agronomic and physiological characterisation of many important crops (Nazarea, 1998). Even basic information, such as common names, that does exist is hard to locate because genebank catalogues are notoriously complex (Pinheiro de Carvalho, 2012); new data portals such as GENESYS (www.genesys-pgr.org) and Global-GRIN (www.grin-global.org) offer hope of easier access.

The genetic resource collectors of the 20th century, such as Jack Harlan and Nikolai Vavilov, were keenly interested in the traditional uses of plants, and were careful recorders in field notebooks and photographs. Many of the data they collected were published, but cannot easily be connected to relevant plant accessions. The collecting notebooks of these pioneers have great potential as research resources if digitised and cross-linked to the relevant accessions still held in genebanks.

In the 1980s, the importance of indigenous knowledge became more widely appreciated, and formal procedures were instituted for its collection alongside germplasm. Guarino & Friis-Hansen (1995), Nazarea (1998) and Quek & Friis-Hansen (2011) give detailed guidance on making traditional knowledge journals and on 'memory banking', a procedure analogous to 'seed banking'. Many of the procedures will be familiar to the ethnobiologist, but working with crops and domesticated animals does require background knowledge to enable the right questions to be asked.

There are significant obstacles to the preservation and transmission of indigenous knowledge once plants reach *ex situ* preservation, for example in a genebank. Knowledge can be hard to preserve in written form, particularly in a form compatible with the databases used to store genebank data. Access to indigenous knowledge will, of course, be framed by the agreements made with the holder of that knowledge. As in the wider world of ethnobotany, these issues are still not fully resolved (Chapter 1).

CONCLUSIONS

The worlds of genetic resources and ethnobiology share common aims and overlapping methodologies, yet hardly interact. Greater engagement between the two would lead to enhanced preservation of biodiversity, the opportunity for more nuanced investigation of research problems, and a greater flow of benefits from germplasm repositories to local communities.

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