COUNTRY REPORT ON THE STATE OF PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

UNITED STATES OF AMERICA

June 2011

Note by FAO

This Country Report has been prepared by the national authorities in the context of the preparatory process for the Second Report on the State of World's Plant Genetic Resources for Food and Agriculture.

The Report is being made available by the Food and Agriculture Organization of the United Nations (FAO) as requested by the Commission on Genetic Resources for Food and Agriculture. However, the report is solely the responsibility of the national authorities. The information in this report has not been verified by FAO, and the opinions expressed do not necessarily represent the views or policy of FAO.

CONTENTS

ACRONYMS AND ABBREVIATIONS

APHIS	USDA Animal and Plant Health Inspection Service
ARS	USDA Agricultural Research Service
CGC	Crop Germplasm Committee
CGIAR	Consultative Group on International Agricultural Research
CPC	Center for Plant Conservation
CSSA	Crop Science Society of America
DBMU	GRIN Database Management Unit
DELEP	The Desert Legume Program
DOI	Department of the Interior
FAO	Food and Agriculture Organization of the United Nations
FS	USDA Forest Service
FWS	U.S. Fish and Wildlife Service
GRIN	Germplasm Resources Information Network
GRIN-CA	Germplasm Resources Information Network of Canada
IARC	International Agricultural Research Center
IICA	Inter-American Institute for Cooperation on Agriculture
INIEA	National Institute of Agricultural Research and Extension of Peru
IBPGR	International Board for Plant Genetic Resources
IPGRI	International Plant Genetic Resources Institute
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
NAPCC	North American Plant Collection Consortium
NARI	National Agricultural Research Institute of Guyana
NCGRP	National Center for Genetic Resources Preservation
NGO	Non-Governmental Organization
NGRAC	National Genetic Resources Advisory Committee
NGRL	National Germplasm Resources Laboratory
NGRP	National Genetic Resources Program
NORGEN	Plant Genetic Resources Network of PROCINORTE, the Northern Region Cooperative Program of IICA
NPDRS	U.S. National Plant Disease Recovery System
NPGS	U.S. National Plant Germplasm System
NSSL	National Seed Storage Laboratory
PEO	Plant Exchange Office, National Germplasm Resources Laboratory
PGRFA	Plant Genetic Resources for Food and Agriculture
PGRPP	Plant Genetic Resources Preservation Project, NCGRP
PGPR	Plant Germplasm Preservation Research Project, NCGRP
RNA	Research Natural Area
SOS	Seeds of Success
SSE	Seed Savers Exchange
TNC	The Nature Conservancy
U.S.	United States of America
USDA	United States Department of Agriculture
USAID	United States Agency for International Development

EXECUTIVE SUMMARY

Plant genetic resources (germplasm) are clearly the foundation of the United States of America's (U.S.) ca. $150 billion annual crop production. The U.S. government has been actively involved in the collection and preservation of plant germplasm since the early 1800s. The U.S. National Plant Germplasm System (NPGS) has the primary responsibility for the *ex situ* preservation of germplasm collections of crop plants and their wild relatives in the U.S.

The NPGS currently maintains over 536 000 accessions of more than 13 000 species in its working collections. Over 71% of the accessions maintained in the working collections are also backed up or held in long-term storage at the National Center for Genetic Resources Preservation (NCGRP). Accessions not yet backed up at the NCGRP include those that were recently acquired and are awaiting regeneration, those for which there is not a sufficient quantity of seed available because of failed or insufficient increase, and a large number of vegetatively propagated accessions maintained by the National Clonal Germplasm Repositories. Since the early 1980s, passport, evaluation, inventory, and distribution data on NPGS collections have been maintained on the Germplasm Resources Information Network (GRIN), a centralized database readily accessible via the Internet.

During the past ten years, approximately 4 900 accessions (8 000, if genetic stocks are included) have been added to the NPGS collections annually. The demand for germplasm from the NPGS remains strong. In response to requests from plant breeders and other scientists, the NPGS distributed an average of almost 170 000 accessions annually between the years 2000-2009. Approximately 70% of the accessions were distributed to U.S. scientists and 30% to foreign scientists, including scientists at the Consultative Group on International Agricultural Research Centers. Although the germplasm contributes extensively for cultivar improvement, it is also used for a wide variety of other scientific studies, most of which ultimately contribute to improvements in agricultural production. During the last decade, there has continued to be a shift of plant breeding research from the public to the private sector in the U.S.

The U.S. has continued to maintain a policy of providing unrestricted access to all public germplasm held in NPGS genebanks. The U.S. has signed the International Treaty on Plant Genetic Resources for Food and Agriculture and as required under U. S. law the President has sought the advice and consent of the U.S. Senate to ratification. NPGS curators are authorized to accept material covered by the Treaty's Standard Material Transfer Agreement and to distribute it under the terms of those agreements which are consistent with the Treaty.

The acquisition of new accessions and the periodic need to regenerate seed to maintain sufficient quantities of viable accessions in the base and working collections challenge the NPGS's annual budget. Appropriations for the NPGS have remained essentially static in recent years; however, increased operating costs make it increasingly difficult to maintain historic levels of activity and service.

Personnel associated with the NPGS and other U.S. scientists have a long history of cooperation with foreign scientists and genetic resources programs in all aspects of germplasm collection, evaluation, preservation and utilization. Cooperation in the preservation and utilization of PGRFA continues and takes into account complicated issues of ownership, intellectual property rights, and benefit-sharing.

With the exception of some native fruits and nuts, relatively little human food is derived from wild harvested plants in the U.S., but there are numerous wild crop relatives that are native to the country and many hectares of native pasture. The *in situ* conservation of plant genetic resources in the U.S. focuses on the preservation of naturally occurring populations of these crop relatives and forages on publicly and privately owned land. Approximately 271 million hectares of forest and rangeland are managed by federal agencies.

It is anticipated that the use of plant germplasm will continue to increase in future years, as farmers worldwide seek new and improved cultivars of diverse crops to meet the ever-growing demand for food, fiber and industrial products derived from plants. Germplasm currently maintained in *ex situ* collections (both within formal genebanks and breeders' collections) will be the primary source of genes needed to meet this demand.

The continued support and strategic expansion of *ex situ* genebank collections are priorities for the U.S. The management capabilities of existing genebank facilities must be maintained and enhanced to take full advantage of scientific and technological advances. Their infrastructure requires targeted upgrading to ensure long-term genetic resource conservation. To ensure that germplasm collections adequately and efficiently represent the existing genetic diversity, NPGS and other collections should be rationalized through regional and international collaboration and gaps filled through exchanges and/or plant explorations. Increasing the percentage of NPGS accessions that are backed up is critical, as is the enhancement of the information-management capabilities of the GRIN database to better manage NPGS data.

INTRODUCTION TO THE UNITED STATES OF AMERICA AND ITS AGRICULTURAL SECTOR

The United States of America is the fourth largest country in the world, with an area of 3 618 770 square miles (9 809 155 square kilometers). In 2008, its population exceeded 300 000 000. The terrain of the 48 conterminous states features a large central plain drained by the Mississippi River system, with the high Rocky Mountains and Sierra Nevada in the western region, and the lower Appalachian Mountain range in the eastern region. Deserts are located in the southwestern states of Arizona, California, Nevada, New Mexico, Texas, and Utah. The average annual temperature ranges from 25º C in southern Florida down to -12º C in northern Alaska. Annual rainfall ranges from a statewide low of 241 mm in Nevada to as much as 1 618 mm in Hawaii, although unique environments in some states are drier than the driest statewide average or wetter than the wettest.

Farmers utilize a wide variety of farming practices and management systems--that differ by region, commodity grown, and farm and operator characteristics--to produce food and fiber for the U.S. population and for export. The size of the country, large areas of arable land, diversity of soil types, availability of adequate amounts of high-quality water, length of growing seasons, and diversity of climates make it possible for U.S. farmers to produce a large proportion of many of the crop plant and domestic animal species needed to meet the demands of the country's ethnically diverse population. In addition, in a typical year, the production equivalent from almost one-fourth of U.S. crop land moves into export markets.

The 2007 U.S. Census of Agriculture (USDA, 2009) revealed that there were 2 204 792 farms, with an average size of 418 acres (169 hectares). Of the 922 095 840 acres (373 158 947 hectares) of farmland, 309 607 601 acres (125 293 750 hectares), or approximately 33% of the total, were used in crop production, with the remainder in idle cropland, pastureland, rangelands, and woodlands.

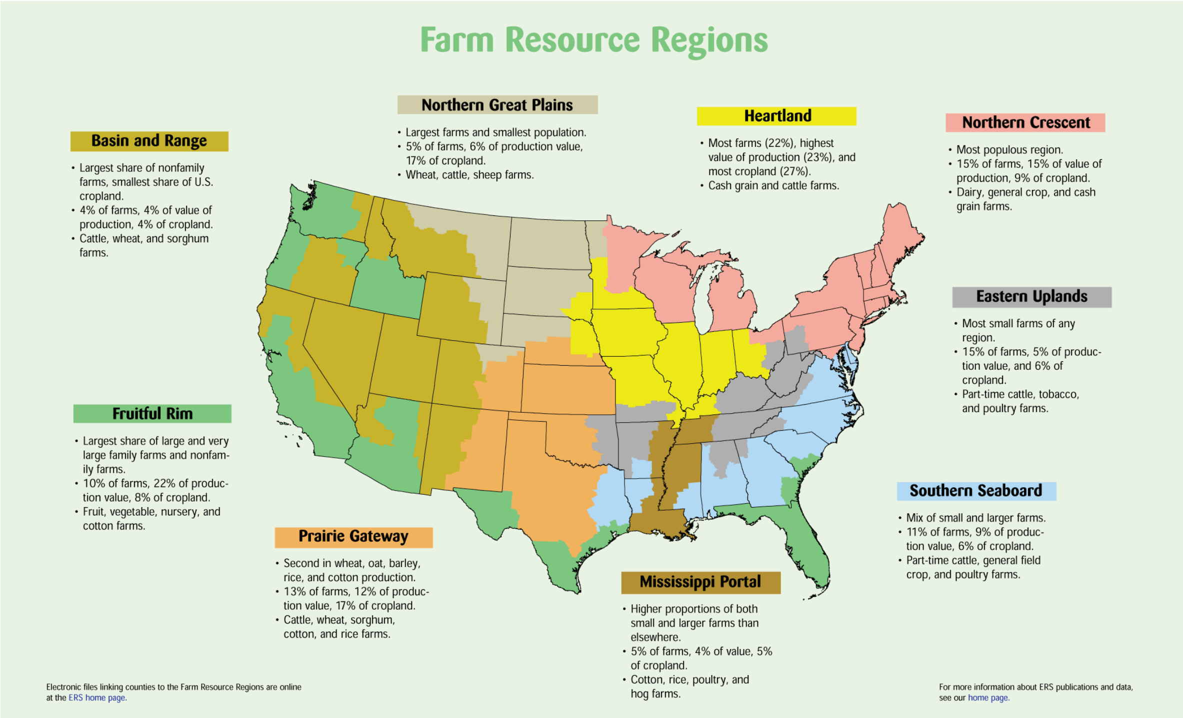
The USDA Economic Research Service identifies nine major farm-production regions in the country (Figure 1). The analysis used to construct these regions is described on the ERS website (http://www.ers.usda.gov/Briefing/arms/resourceregions/resourceregions.htm#usda). Although the production of certain crops tends to be concentrated in certain regions (i.e., corn and soybeans in the Heartland, wheat in the Northern Great Plains and Prairie Gateway, and fruits and vegetables in the Fruitful Rim); almost without exception, every major crop is likely to be grown in more than one region.

Approximately 87% of U.S. farms are classified as family or individual operations, and these account for the largest share of the farmland and gross farm sales. Although partnerships, cooperatives and corporations make up a very small share of the farms, they have the highest average farm sales. For all practical purposes, there are no subsistence farmers in the country, although approximately 17% of farm households had household incomes below the government's official poverty threshold in 2007.

Most farms in the U.S. are small, with 60% of all farms reporting less than $10 000 in sales of agricultural products. Of the 2.2 million farms nationwide, only 1 million show positive net cash income from the farm operation. The remaining 1.2 million farms depend on non-farm income to cover farm expenses.

FIGURE 1

Nine Major Farm Resource Regions in the U.S.



In 2007, the market value of U.S. agricultural products was over $297 billion. The value of crops, including nursery and greenhouse crops, was over $143 billion or about 48% of the total agricultural production. The value of production of more than 25 crops exceeded $500 million in 2007. These included corn, wheat, barley, soybeans, forage crops (alfalfa and all other), cotton, rice, sorghum, ornamentals, sugarbeets, sugarcane, peanuts, potatoes, dry beans, citrus, apples, grapes, strawberries, almonds, broccoli, sweet corn, tomatoes, onions, sunflowers, lettuce, carrots, and pistachios.

CHAPTER 1

THE STATE OF DIVERSITY

1.1 The main values of plant genetic diversity

U.S. farmers grow a wide range of crops, including cereal, oil seed, forage, sugar, vegetable, fruit and nut, and landscape or ornamental species. The acreage harvested, production, and value of production for major crops produced in the U.S., according to the 2007 Census of Agriculture, are provided in Table 1. The production figures for individual fruit and vegetable crops are not shown, although the production value of many of these greatly exceeds that of some of the agronomic crops shown in the table.

TABLE 1

The number of acres harvested, production, and value of production of crops grown in the U.S. in 2007.

Crop	Acres	Production	Value of production (in 1,000 Dollars)
Corn (grain)	86 248 542	12 738 519 330 bushels	52 090 108
Corn (silage)	5 979 661	104 224 795 tons	
Soybeans	63 915 821	2 582 423 697 bushels	26 752 197
Hay (all)	58 121 003	138 113 218 dry tons	16 960 936
Wheat	50 932 969	1 993 648 378 bushels	13 669 482
Cotton	10 493 238	18 898 128 bales	5 196 688
Sorghum (grain)	6 769 834	482 452 865 bushels	1 950 936
Fruits & Nuts (all species)	5 301 236	Note: because of the great diversity of products there is no single unit for measuring production of all these crops	17 853 647
Vegetables (all species)	3 550 625	(Same as above)	12 514 820
Barley	3 521 957	207 089 232 bushels	851 682
Rice	2 758 792	198 538 690 cwt	2 273 955
Sunflowers	2 000 153	2 820 962 445 pounds	606 991
Oats	1 509 149	89 508 669 bushels	228 613
Dry Beans	1 455 549	25 353 900 cwt	677 446
Sugarbeets	1 253 817	31 937 325 tons	1 526 209
Potatoes	1 131 963	444 875 cwt	3 197 746
Peanuts	1 200 564	3 703 138 887 pounds	762 646
Sugarcane	846 666	31 127 405 tons	897 435

(USDA, 2009)

All of the crops listed in Table 1, except cotton, are important for U.S. food security. Most are consumed directly by humans in many different forms, and hay, corn, sorghum and barley are also important sources of feed for animal production. In addition, many of the crops, including corn, soybeans, sunflower and peanuts, have substantial economic value for industrial uses. Corn and soybeans, in particular, have become important in recent years for the production of ethanol and biofuels to supplement petroleum-based fuels for vehicles and other uses.

Since virtually every crop, or crop group, is grown in more than one geographic area, it is important that farmers have access to a wide range of genetically diverse cultivars that can be grown successfully under different soil and climatic conditions and withstand a variety of pests and diseases. U.S. farmers have available to them scores of cultivars of most crops produced in the country, with more than 200 cultivars of some crops available.

1.2 Diversity within and between crops

Some wild plants collected from public and privately owned lands, including wild rice (*Zizania*), low-bush blueberries, pecans, and maples for sugar, are significant sources of human food in the U.S. In Chapter 2, the involvement of numerous governmental and non-governmental agencies in surveying the flora of publicly and privately held lands, including state and national parks, forests, wildlife refuges and other protected areas, will be discussed. These efforts are not typically directed specifically towards the preservation of wild plants for food production and crop-associated biodiversity, representing an area for re-doubled attention in the future.

The overwhelming majority of plant-derived foods consumed in the U.S. is furnished by cultivars. The range of genetic diversity in the major and minor crops grown in the U.S. varies from crop to crop, as do trends in genetic diversity in the standing crop, in breeding programs, and in reserve. Cultivars of many crops grown in the U.S. are frequently replaced with improved cultivars as plant breeders make conscientious efforts to utilize diverse parental material to introduce improved resistance to biotic and abiotic stresses and greater adaptation to environmental conditions.

Although most have been replaced by modern cultivars, some landraces or farmers' varieties are still grown in the U.S. Although not all landraces or farmers' varieties formerly grown in the country have been collected and saved, thousands of samples are preserved in *ex situ* collections by the National Plant Germplasm System (NPGS) and other organizations in the public and private sectors.

1.3 Factors influencing the state of plant genetic diversity in the U.S.

The acreage of individual crops grown varies somewhat from year to year based on demand, production costs, and government policies, which affect cropland availability and revenue protection. Over the past ten years, the acreage of corn and soybeans has increased significantly, while the acreage of wheat, barley, oats and cotton has decreased.

The role and value of the diversity of plant genetic resources are understood and appreciated by the scientific community and important segments of U.S. agroindustry and commodity groups. Scientists involved in research on individual crops (or their genepools) and others involved in various commodity groups, are interested in and concerned about possible decreases in genetic diversity and assume responsibility for informally monitoring or assessing the threat of erosion. Crop Germplasm Committees (CGCs), described in more detail in Chapter 3, analyze and prepare reports on the status of genetic resources of their crops (http://www.ars-grin.gov/npgs/cgclist.html).

Specific knowledge about the diversity represented in the pedigrees of available cultivars is one means used to monitor possible genetic erosion. Also phenotypic observation of different morphological traits and tests to measure response to specific disease-producing organisms or production environments are also used to assess genetic diversity. However, the most definitive information on genetic distance among cultivars and the overall diversity represented is likely to be obtained by analysis of molecular (DNA) markers, and such tests are increasingly applied to assess the diversity of cultivars, as reviewed by Spooner *et al*. (2005).

1.4 Future needs and priorities

Given the complicated, interlocking levels of government (national, state, county, community) and of conservation responsibilities (public-sector, private-sector), the U.S. does not have a single overall plan, or overarching set of specific priorities, for monitoring genetic erosion within specific crops or across all crops. Although the scientific knowledge exists to assess the state of diversity of plant genetic resources, the available funding is insufficient to employ an adequate body of scientifically trained personnel to regularly conduct the required studies for the large number of pertinent crops and crop genepools.

1.5 State of the art

As previously noted, a range of techniques is available to assess plant genetic diversity, erosion and vulnerability (see Engels *et al*., 2002). Continual efforts must be made to inform agricultural research administrators and legislators of the need for adequate financial support for conserving plant genetic resources, including the monitoring of genetic diversity in agricultural production.

CHAPTER 2

THE STATE OF *IN SITU* MANAGEMENT

2.1 Inventories and surveys - assessments and priorities

The *in situ* conservation of crop genetic resources, both wild and cultivated, is recognized as a valuable complementary strategy to *ex situ* seed banks and clonal genebanks (e.g., Bretting and Duvick, 1997). Although few wild plants are used for food production in the U.S., there are numerous species native to the country that are progenitors, or wild relatives, of modern agriculturally important grain, fruit, nut, vegetable, forage, turf, and industrial crops, and also many naturalized wild crop relatives from the Old World. These species occur as a part of natural ecosystems and as weeds in many agroecosystems on public and private lands throughout the country.

For the most part, *in situ* conservation of naturally occurring wild crop relatives occurs fortuitously on protected lands and wilderness areas. There are approximately 271 million hectares of forest and grassland in the U.S. managed by federal agencies. The federal agencies that manage the largest areas of land are the Department of the Interior (DOI)'s Bureau of Land Management (BLM) at 103.6 million hectares, Fish and Wildlife Service (FWS) at 38.9 million hectares, and National Park Service at 34.2 million hectares, and the Department of Agriculture's Forest Service (FS) at 77.6 million hectares. The DOI's Bureau of Indian Affairs, as well as the Department of Defense, the Department of Energy, and the Tennessee Valley Authority also manage large parcels of protected land. Management of these lands involves the conservation of native plants, often focused on rare and endangered species. In addition, state and local governments in all 50 states manage thousands of protected areas, and, thus, are also active in monitoring and protecting rare plants.

Within the land managed by the FS, the U.S. Congress has set aside 14 million hectares of National Forest and National Grasslands as wilderness. The FS has also designated over 202 000 hectares as more than 430 Research Natural Areas (RNAs) that are permanently protected, in part for the purpose of maintaining biological diversity. The other federal agencies listed above are also responsible for managing wilderness tracts and many have established RNAs or their equivalents. Very few complete inventories of biodiversity have been conducted for these or other protected areas. Recently, several private organizations have joined with the National Park Service to conduct inventories of all the species in several parks, under the auspices of the All-Taxa Biodiversity Initiative Alliance of Discover Life in America, Inc. (http://www.atbialliance.org/).

The Endangered Species Act of 1973 gave the FWS's Endangered Species Program the authority to designate plant and animal species as threatened or endangered, and to take appropriate steps to conserve habitat and protected species and reintroduce species to their native habitat. The Act also requires federal agencies to ensure that their activities do not jeopardize the existence of species of plants and animals designated as endangered or threatened or adversely modify designated critical habitat. Recovery plans have been developed for more than 600 of the designated flowering plant species. In addition to the species now listed as threatened or endangered, there are currently 130 plant species that are candidates for listing. Many states also confer some degree of protection to state-designated endangered and/or threatened plant species within their jurisdictions.

Based on data in the taxonomy section of the Germplasm Resources Information Network (GRIN) database, at least 177 of the more than 740 plant taxa listed as threatened or endangered by the FWS are congeneric with taxa identified as agronomic or horticultural crops (see http://www.ars-grin.gov/cgi-bin/npgs/html/croplist.pl for a list of these crops). All of these threatened and endangered species merit protection because of their potential to provide unique genetic material for crop improvement. The emergence of an array of biotechnologies makes genes from wild crop relatives increasingly accessible for crop breeding and improvement; thus, their conservation is likely to be even more important in the future than previously anticipated.

It is important to note that although designation by the FWS or various states gives protection to endangered and threatened plant species, it is not designed to protect individual populations with unique traits nor does it protect rare cultigens. For agricultural purposes, unique traits at a population level are often of great value and may be specifically targeted for conservation.

In addition to governmental agencies, many individuals and private non-profit organizations are involved in conservation programs on privately owned land. The Nature Conservancy (TNC; see http://www.nature.org/) is a non-profit conservation organization that manages approximately 1 500 preserves in the U.S. and protects rare and endangered species and unique ecological communities, primarily through habitat preservation. Although these preserves were not specifically designed for the conservation of wild crop genetic resources, they serve this purpose in many cases. The databases of the State Natural Heritage Programs initiated by TNC contain information on the occurrences of rare species and their habitats in each state.

The Center for Plant Conservation (CPC; see http://www.centerforplantconservation.org/) is a network of 36 botanical institutions sharing a mission to conserve and restore rare native plants of the U.S. The CPC's National Collection of Endangered Plants contains samples of more than 700 of the country's most imperiled native plants. Live plant material is collected from nature and then maintained as seeds, rooted cuttings or mature plants by participating botanical institutions that study and hold the material in protective custody. After propagating the plants, these institutions provide seeds or vegetative propagules to federal and state agencies and private land-management organizations to assist in their efforts to restore imperiled plants in the wild.

Surveying and inventorying naturally occurring plant genetic resources, including crop-associated biodiversity, should be conducted on a continuing basis (see Heywood and Dulloo, 2005). Although the scientific expertise to improve inventories and surveys currently exists throughout the various levels of government and the private sector, the greatest constraint to progress is sufficient funding to adequately support the number of scientifically trained personnel required to carry out the studies. In the future, the shrinking pool of field botanists being trained within the U.S. educational system will likely be an additional constraint.

2.2 On-farm management and improvement of plant genetic resources for food and agriculture

Although the number of Native American farmers in the U.S. is small, a few do still grow traditional varieties of crops and preserve the traditional farming practices of their ancestors. Many of the traditional landraces previously grown by native farmers are very rare or may be extinct. Several Native American tribes (for example, the Oneida in Wisconsin, the Pawnee in Nebraska, and the Zuni in New Mexico) are striving to revive use of their traditional crop varieties, especially of maize, for cultural, religious and health reasons. In addition, other small farmers and hobbyists grow heritage varieties of diverse origins, including Native American varieties, more recent American varieties (for example, *Brassica oleracea* var. *viridis*, commonly known as collards), and Old World varieties brought by immigrants at some point since colonization. The federal government does not provide incentives to farmers to conserve traditional cultivars, nor has it established a forum for stakeholders involved in on-farm conservation. However, some state and local governments and NGOs do support promotional and marketing programs that help incentivize specialized, local horticultural production. One prominent example is the Organic Seed Partnership/Northern Organic Vegetable Improvement Collaborative. During a ten-year period, organic farming organizations, several U.S. land-grant universities and the USDA/ARS NPGS site in Geneva, NY established a national network of organic vegetable breeders and producers who are conserving and improving heirloom vegetables for organic production (see http://www.plbr.cornell.edu/psi/OSP%20home.htm).

There are formal and informal groups and conservation networks in the U.S. that maintain traditional crop varieties. For example, Native Seeds/ SEARCH (see http://www.nativeseeds.org/) is a conservation organization in Arizona involved in the preservation of traditional crop varieties that originated in Native American and colonial communities of the Southwest U.S. and Northwest Mexico, and their wild relatives. This organization distributes seeds to approximately 4 000 farmers and gardeners each year, including Native Americans, and conducts an outreach program to promote the use of traditional crop varieties in indigenous communities. Another organization, the Seed Savers Exchange (see http://www.seedsavers.org/), with headquarters in Decorah, Iowa, is a nonprofit network of gardeners and farmers who maintain and distribute heirloom varieties of many vegetables and fruits.

Many seed companies offer heirloom varieties for sale, with some small companies focusing exclusively on them. No formal system exists in the U.S. to support local or small-scale seed production, but state and county extension personnel and extension-sponsored groups, such as Master Gardeners, are often available to assist. Unfortunately, budget reductions have curtailed the activities of many agricultural extension service offices around the country in recent years.

Farmers in the U.S. are rarely involved directly in the breeding of new cultivars. However, farmers do have opportunities to communicate their ideas and specific needs to public research and extension personnel and representatives of private seed companies, both individually and through discussions at local, state and regional grower meetings. Farmers also can cooperate with public and private breeding programs by participating in on-farm tests of advanced-generation breeding lines and newly released cultivars. They may also serve on boards of directors and advisory committees of private companies, producer cooperatives, universities, and agricultural experiment stations.

For the most part, the system for marketing seeds and propagating materials in the U.S. provides farmers with many avenues of access to a wide range of planting material. In addition to the large companies that supply the largest quantity of seed and other types of propagules, there are numerous small companies, crop-improvement associations, and individuals that can provide a wide range of planting materials for selected crops.

In general, U.S. farmers can market products originating from traditional and underutilized cultivars and crops, subject to the national (e.g., Federal Seed Act), state, and local standards applied to "conventional cultivars." But, in some cases such standards can complicate such marketing, so that special provision might be required. Occasionally, state and local governments or individuals provide assistance to farmers to help develop and promote markets for products from local, traditional or underutilized cultivars and crops. But, we are unaware of any changes in national policy frameworks with regard to on-farm management of plant genetic resources, nor of any policy changes planned.

2.3 Restoring agricultural systems after disaster

Crop agricultural disasters can take many forms. Epidemics of virulent diseases can sometimes cause such severe and widespread damage that they can be considered disastrous. To prepare for these recurrent epidemics, the U.S. established a National Plant Disease Recovery System (NPDRS) through the Homeland Security Presidential Directive Number 9 (HSPD-9) in 2004. The NPDRS seeks to ensure that the tools, infrastructure, communication networks, and capacity required to mitigate the impact of high-consequence plant disease outbreaks are available so that an acceptable level of crop production in maintained in the U.S. USDA, the American Phytopathological Society, U.S. universities, and the U.S. seed industry have compiled or are compiling recovery plans for the most severe diseases threatening U.S. crop production. Crop genetic resources containing resistance genes are often critical elements of these plans. For more details, see http://www.ars.usda.gov/research/docs.htm?docid=14271.

Rangeland and forage resources have also been subjected to extensive damage from wildfires, especially in the western U.S., and the spread of invasive plants. To prepare for such disasters and their mitigation through the re-establishment of stable, native plant communities, in 2001, the DOI's BLM established the Seeds of Success (SOS) program (see http://www.nps.gov/plants/sos/). SOS has developed a partnership of federal government agencies and non-governmental organizations that share the goal of conserving native plants and their communities. SOS supports collection of seed from native plant populations in the U.S. to increase the number of species, geographically appropriate material, and amount of seed available for use in stabilizing and rehabilitating land, and restoring it after disasters.

2.4 *In situ* conservation of wild crop relatives and wild plants for food production

As noted above, wild crop relatives, along with a few wild plant species directly harvested for food, occur on protected, publicly and privately owned lands. Managers, botanists and other employees working on these lands are aware of the importance of surveying to identify which species occur on these lands and of protecting them, but resources are often lacking to carry out these activities. However, many land managers are not aware of the special significance of wild crop relatives. In addition, it is typically difficult for federal, state and local officials, and private organizations concerned about plant conservation to communicate the importance of habitat preservation and *in situ* conservation of plant genetic resources to private land owners, but efforts are made to do so. Various conservation organizations, such as native plant societies, prairie networks, wildlife federations, and state natural heritage foundations, do develop outreach projects and collaborate closely with land owners to promote habitat preservation and restoration.

Overall, the greatest limitations to *in situ* conservation of plant genetic resources are identifying the locations of populations and protecting the plants' natural habitats. Efforts need to be expanded to ensure that more areas are surveyed so that plant populations are identified and appropriate actions are taken to ensure their survival. If necessary, unprotected areas which harbor populations of plant genetic resources, especially those that are rare or have unique characteristics, should be secured and protected from habitat destruction. Threats to habitats include agricultural, residential, and commercial development, encroachment by invasive species, changes in fire and grazing regimens, climatic change, pesticide and herbicide use, overexploitation, and a variety of other factors. In addition to identifying the existence and locations of populations of important plant genetic resources, it is important to assess the genetic and breeding-system variation within and among populations to help ensure that diversity within species is maintained.

Perhaps the greatest need for improving *in situ* conservation of native crop genetic resources is improved communication within and among the large number of public and private organizations and individuals involved. Individuals at all levels within land-management agencies need to be alerted to the presence of wild crop genetic resources on their lands so that proper management practices are instituted to protect these resources. The information in government, TNC State Natural Heritage Program, and natural-history collection (herbarium) databases should be linked to facilitate conservation and monitoring of valuable genetic resources. The designation of areas of existing parks, wildlife refuges, or other protected areas known to contain wild relatives of crops, such as *Vaccinium*, *Carya*, and *Rubus* species, as *in situ* reserves, may help ensure their conservation. Also, the status of species or populations conserved in these areas needs to be carefully and periodically monitored.

2.5 State of the art

Currently, the *in situ* management of plant genetic resources in the U.S. primarily involves surveys and observations on public and private lands to confirm the existence of plants of various species, with documentation of findings in a database, and attempts to prevent damage or destruction of the plants' natural habitats. With the exception of a few species, little has been done to study the genetic diversity that exists between and within identified populations. The latter could provide important information about unique populations that merit special attention. This body of research has slowly expanded, but training of additional field botanists is required to sustain an adequate work force for assessing and protecting populations of wild crop relatives and other plants.

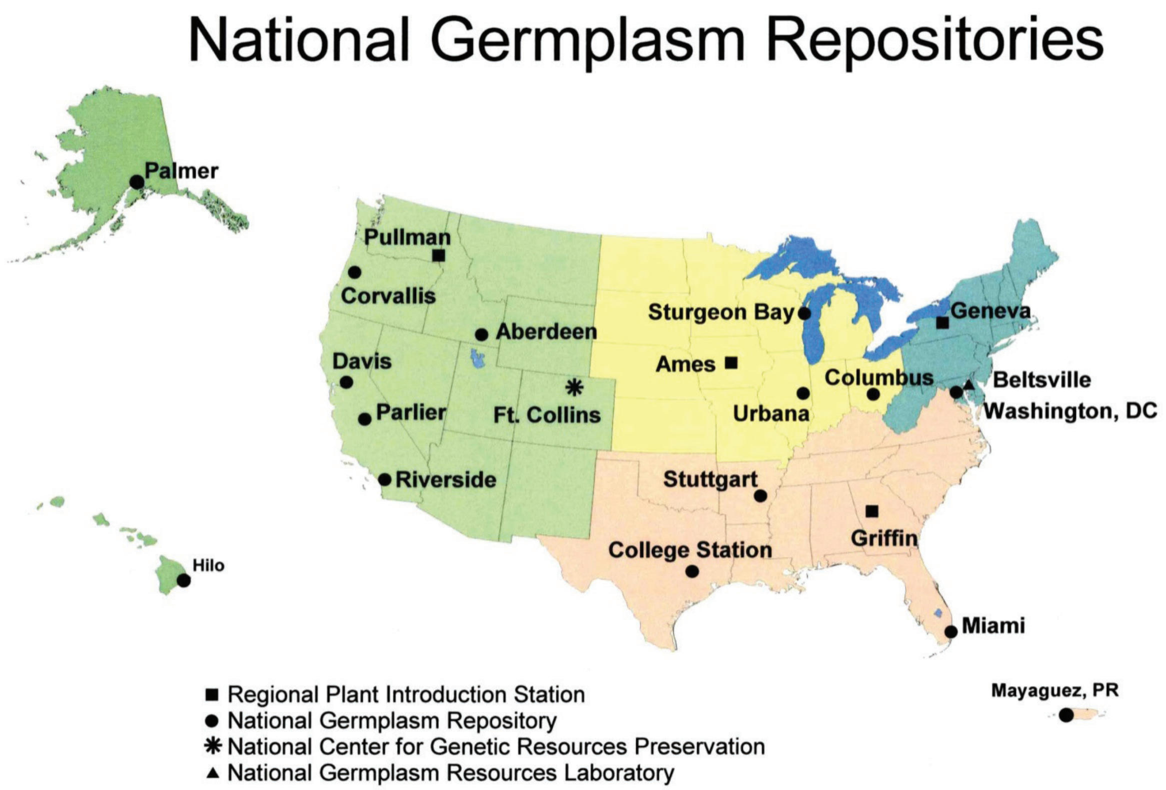
CHAPTER 3

THE STATE OF *EX SITU* MANAGEMENT

3.1 Sustaining and expanding *ex situ* collections

The U.S. National Plant Germplasm System (NPGS) has the primary responsibility for the *ex situ* preservation of germplasm collections of crop plants and their wild relatives in the U.S. The NPGS is a network of Federal, State, and private organizations and research units, coordinated by the U.S. Department of Agriculture, Agricultural Research Service (ARS).

FIGURE 2
Map of U.S. National Plant Germplasm System Locations



During the past ten years, the NPGS's operational components, comprising a network of working or active collections, a base (or safety-duplication) collection, and support units, continued to acquire, document, evaluate, regenerate, and distribute germplasm accessions. As of September 2010, the NPGS collections included more than 536 000 accessions representing more than 13 000 species. The collections include modern cultivars, inbred parental lines, elite breeding lines, landraces or farmer's varieties, wild and weedy relatives of crop species, wild species that may be needed for other purposes (revegetation, potential new crops, chemical analyses), and some rare and endangered species. Approximately 75% of the accessions are originally from foreign sources and 25% are of domestic origin. The number of accessions added yearly to the NPGS has averaged approximately 4 900 (8 000, if genetic stocks are included) during the past ten years. As of September 2010, more than 82% of the accessions in the NPGS are available for distribution.

The efforts and holdings of the NPGS working collections are complemented by a diverse array of institutions, including botanic gardens and arboreta, breeders' collections (both public and commercial), independent genetic stock centers, and NGOs. Inter-relationships between these institutions and the NPGS are described later in this chapter.

Each of the NPGS working collections is responsible for the full continuum of activities associated with preservation of specific plant genera. The locations of the working collections by type, a listing of some of the primary crops or crop genepools maintained by each, and the number of accessions they currently hold, are shown in Table 2.

Within the NPGS, four Regional Plant Introduction Stations are responsible for maintenance of over 234 000 accessions of more than 1 400 genera and 7 500 species, or nearly ½ of the NPGS collection. Although their designations in the table imply that they are regional in nature, they have national responsibility for maintenance of the taxa assigned to them. The State Agricultural Experiment Stations in the four corresponding geographic regions and the USDA National Institute for Food and Agriculture co-fund these four stations with ARS.

In addition to the Regional Plant Introduction Stations, the NPGS has crop-specific collections of small grain, soybean, cotton, potato, and herbaceous ornamental germplasm at locations shown in Table 2. The small grain, soybean and cotton collections originated largely from an assemblage of individual breeders' collections over a period of many years. Connections between current breeders' collections and the NPGS are enhanced through the membership of many breeders on the Crop Germplasm Committees (CGCs; see http://www.ars-grin.gov/npgs/cgcweb.html). The herbaceous ornamental collection is the newest NPGS collection and was created to serve the large and growing ornamental industry in the U.S. (Tay *et al*., 2004).

TABLE 2
Working Collections of the National Plant Germplasm System by Location

Location	Type	Accessions held	Primary Crops
North Central Regional Plant Introduction Station, Ames, Iowa	Plant Introduction Station	51 000+	Maize, oilseed brassicas, cucurbits, sweet clover, amaranth, sunflower, millets, carrot, flax
Plant Genetic Resources Unit, Geneva, New York	Plant Introduction Station, National Clonal Germplasm Repository	20 000+	Tomato, vegetable brassicas, onion, grape, apple, sour cherry
Plant Genetic Resources Conservation Unit, Griffin, Georgia	Plant Introduction Station	89 000+	Sorghum, sweetpotato, peanut, cowpea, melons, pepper, mung bean, forage legumes
Western Regional Plant Introduction Station, Pullman, Washington	Plant Introduction Station	80 000+	Common bean, onions, chickpea, alfalfa, lettuce, forage grasses, sugarbeet
National Small Grains Collection, Aberdeen, Idaho	Crop	131 000+	Wheat, barley, oats, rice, rye, Aegilops, triticale
Soybean/Maize Germplasm, Pathology, and Genetics Research Unit, Urbana, Illinois	Crop	21 000+	Soybean
U.S. Cotton Germplasm Collection, College Station, Texas	Crop	9 000+	Cotton
United States Potato Genebank, Sturgeon Bay, Wisconsin	Crop	5 000+	Potato
Ornamental Plant Germplasm Center, Columbus, Ohio	Crop	3 000+	Herbaceous ornamental species
National Collection of Genetic Resources for Pecans and Hickories, Brownwood, Texas	National Clonal Germplasm Repository	3 800+	Pecan, hickory
National Clonal Germplasm Repository, Corvallis, Oregon	National Clonal Germplasm Repository	14 000+	Pear, strawberry, raspberry, blackberry, blueberry, hops
National Clonal Germplasm Repository for Fruit and Nut Crops, Davis, California	National Clonal Germplasm Repository	6 800+	Grape, stone fruits, walnut, almond, olive, pistachio, fig, persimmon, mulberry, kiwi, pomegranate

Location	Type	Accessions held	Primary Crops
Tropical Plant Genetic Resources and Disease Research Unit, Hilo, Hawaii	National Clonal Germplasm Repository	900+	Macadamia, pineapple, papaya, lychee, jackfruit, carambola, guava, passion fruit, rambutan, breadfruit
Tropical Agriculture Research Station, Mayaguez, Puerto Rico	National Clonal Germplasm Repository	900+	Banana, cacao, tropical fruits
Subtropical Horticulture Research Station, Miami, Florida	National Clonal Germplasm Repository	4 800+	Sugarcane, mango, avocado, ornamentals
National Clonal Germplasm Repository for Citrus & Dates, Riverside, California	National Clonal Germplasm Repository	1 500+	Citrus and related genera, dates
Woody Landscape Plant Germplasm Repository, Washington, D.C.	National Clonal Germplasm Repository	3 500+	Woody ornamental species
Barley Genetic Stock Collection, Aberdeen, Idaho	Genetic Stock Collection	2 100+	Barley
Maize Genetics Cooperation • Stock Center, Urbana, Illinois	Genetic Stock Collection	6 700+	Maize
G.A. Marx *Pisum* Genetic Stock Collection, Pullman, Washington	Genetic Stock Collection	700+	Pea
Genetic Stocks - *Oryza* Collection, Stuttgart, Arkansas	Genetic Stock Collection	25 800+	Rice
C.M. Rick Tomato Genetics Resource Center, Davis, California	Genetic Stock Collection	3 400+	Tomato
Wheat Genetic Stock Collection, Aberdeen, Idaho	Genetic Stock Collection	940+	Wheat
National Arctic Plant Genetic Resources Unit, Palmer, Alaska	Specialized subarctic environment	430+	Rhubarb, grasses, mint
National Arid Land Plant Genetic Resources Unit, Parlier, California	Specialized warm-season arid environment	1 350+	Lesquerella, meadowfoam, prickly-pear, guayule, jojoba

The National Clonal Germplasm Repositories listed in Table 2 are responsible for the preservation of cultivars, breeding lines and wild relatives of perennial, generally asexually propagated fruit, nut, grass, and ornamentals, as well as some seed-propagated woody landscape crops. The primary focus of the Clonal Repositories (Postman *et al*., 2006) is maintaining living plants, as these must be propagated vegetatively to be maintained true to type. However, some accessions, particularly of wild crop relatives, are stored as seed.

Genetic Stock Collections maintain marker lines, induced and natural mutations, aneuploids, polyploids, cytological variants, and reference and mapping populations. Most Genetic Stock Collections originated as research collections developed by individual scientists over their careers and were determined to merit preservation because of their genetic characteristics and scientific value, but these have evolved to meet the changing needs of genomics and a dynamic research community (Scholl *et al*., 2003). NPGS genetic stock centers are complemented by various independent stock centers in the U.S., generally associated with research universities.

3.1.1 National Center for Genetic Resources Preservation

The National Center for Genetic Resources Preservation (NCGRP) in Ft. Collins, Colorado, is a critical component of the NPGS. The NCGRP was known as the National Seed Storage Laboratory (NSSL) until 2001, when its name was changed to reflect an expanded mission. Its Plant Genetic Resources Preservation Program (PGRPP) manages the NPGS base collection in which duplicate samples of the germplasm from the working collections are safeguarded in long-term storage. NPGS policy is to have duplicate samples of all working-collection accessions backed up at the NCGRP. As of September 2010, the NCGRP held more than 381 000 accessions, ca. 71% of the accessions maintained in the working collections. Accessions not backed up at the NCGRP include those that were recently acquired and are awaiting a seed increase, those that do not have a sufficient quantity of seed available after initial regenerations, and a large number of vegetatively propagated accessions maintained by the National Clonal Germplasm Repositories.

In recent years, technological developments in preserving vegetative buds of many species in liquid nitrogen have made it possible to store and duplicate samples of many accessions from the Clonal Repositories at the NCGRP. Currently meristems and vegetative buds of 4 177 accessions, ca. 9% of the accessions propagated vegetatively by the Clonal Repositories, are being cryopreserved at the NCGRP. These accessions include cultivars, landraces, breeding lines and wild relatives belonging to 187 species in 18 genera. The greatest number of accessions (2 233) is of *Malus* (apple), the genus for which the techniques for cryopreservation of vegetative tissue have been most extensively applied. In addition, other genera being successfully cryopreserved include *Allium* (garlic), *Corylus* (filbert), *Cydonia* (quince), *Cynodon* (bermuda grass), *Fragaria* (strawberry), *Humulus* (hops), *Ipomoea* (sweet potato), *Lolium* (ryegrass), *Mentha* (mint), *Musa* (banana), *Prunus* (stone fruit), *Pyrus* (pear), *Ribes* (currant), *Rubus* (brambles), *Salix* (willow), *Solanum* (potato), and *Zoysia* (zoysia grass).

The NCGRP also stores seeds of more than 18 000 additional accessions that are not represented in the working collections. These accessions are primarily unsolicited seed samples that were sent directly to the NSSL for storage during its early years and were never duplicated in the appropriate working collections. As seeds of these accessions are increased, they are being considered as candidates for incorporation into the working collections.

The Plant Germplasm Preservation Research Unit of the NCGRP evaluates options and develops new approaches for genebanking plant genetic resources to enhance the genetic diversity and security of collections. This group conducts research to develop tools and approaches to enhance longevity of stored germplasm, expand capacity to assess and efficiently capture genetic diversity, and improve methods that validate and predict the viability and genetic integrity of seed lots and vegetative samples. They also develop sampling strategies for wild-collected germplasm that maximize genetic diversity and preserve that diversity in genebank samples.

3.1.2 National Germplasm Resources Laboratory

Another component of the NPGS is the National Germplasm Resources Laboratory (NGRL) in Beltsville, Maryland. The NGRL consists of three units that support the entire NPGS: the Plant Exchange Office; the Database Management Unit; and the Plant Disease Research Unit. The Plant Exchange Office facilitates international germplasm exchange, manages a plant exploration and exchange program to acquire new germplasm, and is responsible for the taxonomic information in the Germplasm Resources Information Network (GRIN) database for plants. The Database Management Unit develops and maintains the GRIN databases for the entire National Genetics Resources Program, including plants, animals, microbes, and invertebrates, and oversees the activities of the CGCs. The Plant Disease Research Unit conducts research to understand the biology of pathogens that infect economically important plant genera that require extensive testing to be allowed to enter the U.S.

3.1.3 Crop Germplasm Committees

A key advisory component of the NPGS is the group of 42 CGCs that work closely with the managers, curators and staffs of the NPGS operational components described above. These committees serve as national working groups of specialists that represent their user community and provide analyses, data and recommendations on genetic resources within a specific crop or group of related crops of present or future economic importance. The CGCs' membership represents various governmental, academic, and private organizations, a range of pertinent scientific disciplines, and geographic areas where the crop(s) is important.

3.1.4 State germplasm conservation

In addition to germplasm collections that are supported by the federal government and those supported through federal-state cooperation, some state governments in the U.S. maintain independent germplasm collections. For example, the *Nicotiana* Germplasm Collection of approximately 2 000 accessions of *Nicotiana tabacum* and 59 species of wild *Nicotiana* is maintained by the North Carolina State University Experiment Station in Oxford, North Carolina.

Nicotiana germplasm is backed up at the NCGRP and is available to order though the GRIN website. Another example is the Citrus Variety Collection of the University of California at Riverside, which includes more than 1 000 different types of citrus within the genus *Citrus* and within 27 of the 33 related genera in the subfamily Aurantioideae of the Rutaceae. These accessions encompass virtually all of the commercially important and historic citrus varieties of the world.

3.1.5 Involvement of non-governmental organizations in germplasm conservation

Many U.S. botanical gardens and arboreta maintain and conduct research on collections of germplasm of ornamental plants. Many of these institutions are members of the American Public Gardens Association, which, in conjunction with the U.S. National Arboretum, coordinates the North American Plant Collection Consortium (NAPCC; http://www.publicgardens.org/content/what-napcc). NAPCC is a program to recognize important *ex situ* germplasm collections and enhance the standards of their curation. Although the mission of many of the participants is to display, conserve and conduct research on species for ornamental or landscape use, there are instances in which the genetic resources conserved by botanic gardens are of direct agricultural importance (primarily of fruit and nut crops), or are related to food crops. Also, as noted in Chapter 2, thirty-six U.S. botanic gardens and arboreta cooperate with the Center for Plant Conservation to conserve and restore rare native plants, some of which are wild crop relatives.

In addition, several botanic gardens are involved in the Seeds of Success (SOS) program, a multi-institutional partnership described in Chapter 2, with the goal of conserving U.S. native plants and their communities. Although SOS focuses on species needed for restoration, many crop wild relatives are among those collected. Seeds from SOS collections are backed up in the NCGRP and, when appropriate, are incorporated into NPGS working collections.

The Desert Legume Program (DELEP) of the Boyce Thompson Arboretum in Tucson, Arizona focuses on collection, preservation, and study of desert legume species from around the world (see http://cals.arizona.edu/desertlegumeprogram/). The DELEP cooperates closely with the NPGS, and its germplasm samples are backed up at the NCGRP. Germplasm from DELEP can be ordered through the GRIN website.

Several private organizations are active in acquiring and maintaining landraces and heirloom varieties. For example, the Seed Savers Exchange (SSE) mentioned in Chapter 2, is a non-profit organization with a member base of about 11 000, whose mission is to help safeguard the world's diverse garden heritage by preserving heirloom varieties and educating the public about the value of agricultural diversity. The SSE is currently preserving more than 25 000 rare fruit, vegetable and other plant cultivars.

3.1.6 Constraints to sustaining and expanding *ex situ* plant genetic resources collections

Over the next ten years, the greatest constraint to sustaining existing *ex situ* collections and making them available for research, and to filling key gaps in those collections, is expected to be the availability of sufficient funding for specialized personnel and facilities. Also, restrictions on international exchange of germplasm limit the possibilities for expanding the collections, as discussed in more detail in the section on Planned and Targeted Collecting.

Given such constraints, the NPGS must develop and adhere to priorities for the effective use of the limited resources which are available for plant genetic resource conservation and sustainable use. Current overarching priorities include:

- Managing and expanding NPGS operational capacity and infrastructure
- Fulfilling the demand for additional germplasm characterization/evaluation
- Acquiring and conserving germplasm of wild crop relatives
- Managing genetic/genomic seed stocks

3.1.7 Documentation

Data on the NPGS collections are maintained in the GRIN database. GRIN is a centralized database that includes passport, taxonomic, inventory, evaluation and order processing records for the NPGS. Documentation of accessions is an ongoing process. Passport, taxonomic, characterization and evaluation data on accessions are available on the Internet. As new information about the origin or correct identification of an accession becomes available, or as additional characterization and evaluation data are obtained, they are incorporated into GRIN. Recent modifications to GRIN now also accommodate molecular data on NPGS accessions.

In collaboration with the Global Crop Diversity Trust and Bioversity International, the NPGS is developing GRIN into "GRIN-Global," a plant genetic resource information management system that can be implemented not only by advanced, centralized, multi-node genebank systems, such as the NPGS, but also by small, independent genebanks in developing nations (see Chapter 5 for more details).

3.1.8 Research priorities to expand and improve *ex situ* conservation

Research to further develop cryopreservation technologies to preserve recalcitrant seed and vegetative tissues is a priority. Also, research is needed to develop or improve techniques to induce flowering and seed production in accessions that do not flower readily. In instances in which it is difficult to induce accessions to flower and produce seed, or the seeds cannot be easily stored, plants are maintained vegetatively and sometimes backed up with one or more duplicate samples at a remote location.

3.1.9 Regeneration of NPGS accessions

The NPGS policy is to regularly monitor and regenerate germplasm accessions maintained as seeds when the supply in the working collection approaches the minimum amount needed for distribution, or when germination tests of the working- or base-collection samples show that seed viability has dropped below the established minimum for a species (usually 85%). Because of the large number of accessions being preserved, the continued acquisition of new accessions, and the depletion of seed supplies to fill requests, seed regeneration is a high-priority activity that consumes a considerable amount of the NPGS's resources. Most of the working collections have a backlog of accessions awaiting seed multiplication.

Although the numbers vary from crop to crop, presently approximately 10% of the seed-propagated accessions in the working collections are unavailable for distribution pending regeneration. Also as indicated above, the nearly 19 000 accessions that are currently held only in the base collection at the NCGRP may require regeneration so they can be considered for selective incorporation into the working collections.

Currently, some working collections are experiencing a reduction in seed availability due to the high demand for seed and the limited resources available for regeneration. In recent years, inadequate financial resources have limited the hiring of an optimal number of scientifically trained technicians and laborers required to carry out needed regenerations, as well as other related field, greenhouse, laboratory and office activities.

In addition to restricting the hiring of personnel, insufficient funding limits access to adequate physical facilities. At some sites, greenhouse space is insufficient to regenerate plants throughout the year or provide the precise conditions that are often needed to produce seeds of certain species or individual accessions. These accessions may require very specific temperature, light, and humidity conditions to grow, induce flowering, and set seeds. The number of screen houses available for growing some species in an insect-free environment also limits seed regeneration capacity. The facilities for field seed increases of most self-pollinated species are sufficient, but the availability of an adequate number of field cages for controlled pollination of cross-pollinated species is sometimes a problem. Limited financial resources often restrict the Clonal Repositories' abilities to grow more than one or two plants of an accession, thus making them particularly vulnerable.

Occasionally, arrangements are made to regenerate seeds of some accessions at a location other than the site of the working collection to take advantage of specialized facilities or growing conditions. This may involve the development of contractual arrangements with individuals, universities, or private companies to regenerate accessions. The longstanding NPGS goal of securing a seed-regeneration site in an arid region with a long growing season was realized in the mid-1990s when land for that purpose was purchased at Parlier, California. The addition of the National Arid Land Plant Genetic Resources Unit at this location increased the NPGS's capacity to regenerate high-quality seed samples and reduce selected backlogs.

3.1.10 Management practices for regeneration

To preserve the health and genetic integrity of NPGS collections, each of the working collections has standard operating procedures for the conservation and regeneration of the species they curate. The procedures detail the minimum number of plants to be grown, isolation requirements, special cultural practices, harvesting practices, etc. It is generally felt that current regeneration and maintenance procedures that include various isolation techniques, using greenhouse, screen house, field cage and spatial plantings, as executed by crop-specific curators, are adequate to ensure genetic integrity and plant health. However, germplasm accessions, by their very nature, are extremely variable; generalized procedures may not be optimal for all accessions.

Periodically, situations occur in which less-than-ideal practices have to be followed during seed increases, such as when the supply of viable seed available for the increase is limited or a heterogeneous accession is grown under suboptimal conditions that can lead to some "genetic bottlenecks." Although there is always a slight risk that pollen flow or co-mixture can occur during seed increase or processing, the NPGS's operating procedures are designed to minimize bottlenecks, selection, genetic drift, and undesirable gene flow.

Details of the regeneration history of accessions are recorded in the GRIN database for internal use by curators and site managers. Records for a few accessions that have been maintained by the NPGS for a long time are incomplete or inaccurate. It is common in accessions with a long history of maintenance to have more than one generation of an accession in storage. Typically, the seeds of these different generations or increases are managed separately and not mixed, although this is not always the case, especially for autogamous crops or when increases are regenerated from the same parental lot.

3.1.11 Priorities for maintaining viability and preventing genetic erosion

The NPGS's priorities for the future include the effective utilization of available funds to maintain the viability of germplasm currently in its collections. Accessions should be regenerated in a timely manner to ensure that an ample supply of high-quality seeds and vegetative propagules is available for backup and to respond to domestic and foreign requests. Particular emphasis must be placed on the backup of vegetatively propagated accessions maintained at the Clonal Repositories. Other priorities are to fill known gaps in the genetic diversity of the collections, with a major focus on collecting and preserving wild crop relatives that are threatened in their native habitats. Another priority is to more extensively evaluate existing accessions.

Although not part of formal or structured backup or duplication plans, large numbers of NPGS accessions have been distributed to foreign national collections and Consultative Group on International Agricultural Research (CGIAR) centers, and some of this germplasm could be reacquired if necessary. However, without easy access to inventory and status information from other genebanks, it is not possible to quantify the extent of duplication or propose effective strategies for reacquisition. For this reason and many others, the NPGS maintains a strong interest in cooperating with CGIAR genebanks and foreign genetic resources programs to ensure that genetic resources are not lost. Complete sharing of information about the content of collections and a commitment to a shared responsibility for germplasm maintenance are critical for long-term efforts to effectively maintain genetic resources. As described earlier, when deployed, GRIN-Global and the Bioversity-implemented GIGA-Genesys database portal should facilitate more extensive worldwide access to information associated with germplasm conserved in genebanks.

3.2 Planned and targeted collecting

The NPGS has a longstanding program to support worldwide plant explorations to fill collection gaps (Williams, 2005). Between 2000 and 2009, the NPGS supported 137 plant explorations to acquire additional germplasm for long-term preservation. In addition to those supported by the NPGS, an undetermined number of plant explorations were conducted during the period by U.S. scientists using funds from other sources. Forty-eight of the NPGS-supported explorations took place within the U.S., and the other 89 collecting expeditions took place abroad in 33 countries. The targeted taxa included a wide range of crop species and their wild relatives, including grain, grass, oilseed, fiber, vegetable, fruit, nut, and ornamental species.

The NPGS Plant Exploration Program is managed by the Plant Exchange Office (PEO) of the National Germplasm Resources Laboratory in Beltsville, Maryland. Proposals for explorations prepared according to detailed guidelines are accepted yearly from researchers and curators and are reviewed by a committee of NPGS personnel and other scientists. Review and endorsement of each proposal by the pertinent CGC (s) are also required. In the rare case in which a proposal targets a crop outside the mandate of any CGC, another qualified expert may serve as a reviewer.

NPGS foreign explorations follow a code of conduct, developed to ensure that ethical and conservation issues are carefully considered. All explorations comply with the tenets of the Convention on Biological Diversity regarding access and benefit sharing related to genetic resources. Prior informed consent to collect genetic resources is obtained from the appropriate host-country authorities before any collecting occurs, unless the host country has determined that its permission is not necessary. The permission obtained usually includes agreement on the benefits to the host country associated with access to genetic resources. The PEO takes the lead in requesting prior informed consent and works with host-country authorities to identify appropriate forms of benefit sharing.

NPGS-supported plant explorations in foreign countries are conducted in full cooperation with the government and scientists of the host country. Cooperation with national genetic resources programs is strongly encouraged. Germplasm collected by the scientists of the two countries is shared for mutual benefit. Additional, nonmonetary benefits are often associated with NPGS plant explorations when mutually agreed upon by USDA-ARS and host-country partners and authorities. The benefit-sharing approach taken by the NPGS is based on the premise that additional support from the NPGS should contribute to the conservation of plant genetic resources in the host country, preferably by strengthening the capacity of its national plant genetic resources program. These benefits have included training of host-country scientists, projects to increase and evaluate germplasm, and support for *in situ* conservation.

During the past 10 years, the NPGS has experienced numerous difficulties in obtaining access to germplasm requested for collection. Such problems have involved delays or failures by national authorities to process applications for access, requests by national authorities for restrictions on germplasm use or distribution that are not consistent with USDA policies, and even the complete absence of responses from national authorities. These experiences ultimately make it impossible for NPGS scientists to collaborate with scientists in some countries on germplasm collection, conservation, and related benefit-sharing activities. It is anticipated these challenges will persist (for an incisive perspective, see Safrin, 2004).

The CGCs have been charged to work with the crop-specific curators to assess NPGS collections, identify gaps, and develop plans to fill them. These efforts are detailed in reports prepared by the CGCs and available on the NPGS web site (see http://www.ars-grin.gov/npgs/cgclist.html). The PEO also assists with the identification of gaps in collections and developing opportunities for exchanges or explorations to fill them. Public and private scientists working with specific crops, but who are not members of a CGC, also often help identify key collection gaps.

3.3 Assessment of major *ex situ* needs

As enumerated earlier, should additional resources become available to the NPGS, they would likely be applied to the following NPGS-wide priorities:

- Managing and expanding NPGS operational capacity and infrastructure
- Fulfilling the demand for additional germplasm characterizations/evaluations
- Acquiring and conserving germplasm of wild crop relatives
- Managing genetic/genomic seed stocks

3.4 State of the art

A wide range of methods is employed by the NPGS to conserve germplasm *ex situ*. These include storing desiccated seeds in refrigerated facilities, cryopreserving seed and vegetative buds, using slow-growth *in vitro* culture, and growing plants in field genebanks. Research conducted at NCGRP and the active repositories is continually advancing the effectiveness of these methods in conserving the viability and genetic diversity of the samples. The primary obstacle to using available *ex situ* methods to maintain sufficient supplies of viable seed or vegetative tissue is inadequacy of funding for trained personnel and specialized facilities. The maintenance of vegetatively propagated accessions of species at the Clonal Repositories is very expensive because of the requirement for greenhouse facilities, land and labor.

CHAPTER 4

THE STATE OF *EX SITU* MANAGEMENT

4.1 Distribution of plant genetic resources

The NPGS policy is to provide free access to all scientists, educators, and other users to public germplasm held in its genebanks. The only exceptions to access occur when accessions are unavailable pending regeneration or completion of quarantine testing, or because of their noxious-weed, endangered-species, or plant-health status.

The total number and percentage of accessions distributed by the NPGS to domestic, foreign, and International Agricultural Research Centers (IARCs) for the period from 2000 to 2009 are summarized in Table 3. The demand for NPGS germplasm from both domestic and foreign requesters remained consistently high during the period. Also, the proportions of accessions distributed to U.S. and foreign requesters remained quite consistent. Although the table only includes data from the past ten years, an analysis of similar data for the past 25 years reveals that the number of accessions distributed annually to U.S. and foreign requesters has increased over time. Since the early 1980s, information on the distribution of germplasm from the NPGS has been recorded in the Germplasm Resources Information Network (GRIN) database.

TABLE 3

Number of National Plant Germplasm System Accessions Distributed to U.S., Foreign, and International Agricultural Research Center Requesters from 2000 to 2009

Year	U.S.	Foreign	IARCs	Total
2000	128 560	41 485	542	170 587
2001	77 306	41 946	867	120 119
2002	87 093	29 148	364	116 605
2003	110 478	42 827	5	153 310
2004	101 182	34 729	2 406	138 317
2005	100 901	36 085	1 365	138 351
2006	101 543	47 884	697	150 124
2007	108 439	60 714	678	169 831
2008	123 593	59 069	216	182 878
2009	161 226	73 742	2 742	237 710
10-year Average	**110 032 (69.7%)**	**46 763 (29.7%)**	**988 (0.6%)**	**157 783**

The numbers of accessions that were distributed to individuals and private companies during the past ten years and the percentage of the total distributions are shown in Table 4. The distributions to private germplasm users remained quite consistent during the past ten years, but again, data for the past 25 years show that over time the total number of accessions requested by private industry increased, as did the percentage of total distributions.

TABLE 4
Number of National Plant Germplasm System accessions distributed to U.S. and foreign individuals and private companies and percentage of the total distributions from 2000 to 2009

Year	Number of Accessions Distributed to Individuals and Private Companies (U.S. and Foreign)
2000	47 723
2001	21 441
2002	37 560
2003	26 205
2004	36 239
2005	35 806
2006	43 283
2007	47 258
2008	53 086
2009	67 142
10-year Average	**41 574 (26.3%)**

Farmers usually do not request germplasm from the NPGS because the collections primarily include obsolete cultivars, genetic stocks, breeding lines, landraces and wild crop relatives, which are of little direct interest to them. However, if farmers do have a need for germplasm that cannot be readily obtained from another source, they can obtain it from the NPGS.

From 2000 to 2009, germplasm of approximately 39% of the species in the NPGS collection was not distributed. Although it is not possible to predict whether there will be requests for many of these species in the future, two factors that may stimulate future interest in these species are 1) searches for potential new crops, and 2) emerging technologies that are making it possible to combine genes from species that were once too distantly related to cultivated crops and their primary genepools.

4.2 Utilization and enhancing the use of plant genetic resources

The consistently large numbers of requests for germplasm reflected in Tables 3 and 4 clearly show that the germplasm maintained by the NPGS is in great demand. The NPGS does not require that germplasm recipients report how (or if) they use the samples that they receive; therefore, we can only assume from the number of requests and reports in the scientific literature that these collections are being widely used.

The use of germplasm in the U.S. and elsewhere has been periodically documented in the scientific literature (e.g., Fowler and Hodgkin, 2004) and at scientific meetings. Symposia held at the 1989 and 1990 annual meetings of the Crop Science Society of America (CSSA) documented in detail how germplasm had been used to improve 16 of the world's most important agronomic crops. The papers presented at the symposia were subsequently published in CSSA Special Publications 17 and 20 (Shands and Wiesner, 1991, 1992). Although 18 years have passed since these symposia, the use of plant genetic resources to develop improved crop cultivars has continued. Similar symposia have been held at American Society for Horticultural Science annual meetings documenting crop improvement of vegetable and fruit crops.

Examples can be cited of the use of plant genetic resources to improve virtually every crop. Two recent examples for potato and barley clearly demonstrate the contribution of plant genetic resources to improvements in crop production.

In 2004, scientists from the USDA/ARS and three state agricultural experiment stations released 'Defender', a high-yielding potato cultivar with foliar and tuber resistance to late blight caused by *Phytophthora infestans* (Novy *et al*., 2006). In addition to late blight resistance, 'Defender' is resistant to tuber early blight, 'potato virus X' and net necrosis, and has moderate resistance to Verticillium wilt, pink rot, foliar early blight, corky ring spot, and Erwinia soft rot. The late blight resistance in 'Defender' is attributed to germplasm that the breeders received from the Polish Plant Breeding and Acclimatization Institute. The original source of resistance in the Polish breeding line is unclear, since diverse wild and cultivated species from Mexico and South America are in its pedigree.

Another example of the use of germplasm to improve a crop involves barley. In 2006, a new cultivar of spring feed barley, 'Sidney,' was released by USDA/ARS scientists and university collaborators (Mornhinweg *et al*., 2009). This variety is resistant to all known biotypes of the Russian wheat aphid, a serious pest of barley throughout the western Great Plains of the U.S. To identify sources of resistance to this insect, the entire NPGS collection of over 28 000 barley accessions was screened. This resulted in the identification of 109 accessions with some level of resistance. Thirty-seven of these accessions were subsequently used to develop the new cultivars. In addition to the two cultivar releases, 36 germplasm lines of malting barley and 14 lines of feed barley were developed and released as parental material to be used by other breeders.

In addition to their use by plant breeders or geneticists to develop improved cultivars for farmers' use, plant genetic resources are routinely used by scientists of numerous disciplines in a wide variety of basic and applied research. A symposium was held at the 2008 CSSA annual meeting to share examples of these diverse uses of plant genetic resources. Uses described at the symposium included research on the following topics: mechanisms of resistance to numerous plant pathogens and insects; pathogen and insect race or strain indicators; plant physiology and morphology studies; abiotic effects of temperature, moisture, soil, plant nutrients, and herbicides on plant growth and development; molecular biology and cytogenetics; phylogenetics and genomics; archaeology and crop domestication; crop management and ecology; and alternative uses of plants for food, energy, industrial products and medicines. Many of these studies generate information which eventually contributes to cultivar development, even though that was not their primary objective. In addition to plant genetic resources' key role in research, educators, ranging from elementary school teachers to professors in colleges and universities, frequently employ germplasm collections for a variety of lessons and demonstrations.

Returning to the use of plant genetic resources for crop improvement or cultivar development, for many crops, such as corn (maize) and soybeans, the cultivars grown by U.S. farmers result primarily from private-sector breeding programs, making it difficult to gauge the precise contribution of NPGS accessions because private pedigrees are usually not disclosed. Nonetheless, private-sector researchers would not continue to request germplasm accessions from the NPGS if they were not valuable in genetics, genomics, or breeding research (as documented by Day-Rubenstein *et al*., 2006). In addition to having access to germplasm from the NPGS, virtually all U.S. breeding programs, both public and private, maintain their own working germplasm collections. The NPGS continually strives to increase awareness among plant breeders and other scientists in the U.S. public and private sectors of the utility of the genetic diversity in its collections through providing information through web sites, written information, and presentations at scientific meetings.

Actions taken by the NPGS to enhance the use of plant genetic resources include characterizing and evaluating accessions (see discussion below) and maintaining an abundant supply of good quality seed or other propagating material for distribution. In addition to making germplasm more useful to plant breeders and other scientists (Day-Rubenstein *et al*., 2006), evaluation for a wide variety of traits improves the understanding of the state of diversity of genetic resources collections.

Characterization of accessions can begin with the recording of various phenotypic traits during the regeneration process, whenever such traits are clearly expressed under regeneration conditions. Evaluation of the germplasm normally follows and may include the observation of accessions grown under a variety of cultural and climatic conditions, when appropriate, subjecting accessions to artificial epiphytotics, and chemical or molecular analyses for specific compounds. Evaluation projects may be conducted by the staff at NPGS working collections or by university, government, or commercial scientists.

For most crops or crop groups, the relevant CGC helps establish evaluation priorities and plans for the NPGS germplasm. These plans typically involve the selection of priority traits and identification of specific expertise, interest and facilities to carry out the evaluations. Limited funding is available each year to support evaluation of germplasm of horticultural crops, and calls for evaluation proposals are made to the scientific community to participate. The resulting evaluation data are made available to the crop-specific curator for entry into the GRIN database.

Most NPGS accessions have some associated evaluation data in GRIN. During the past ten years, more than 308 000 accessions of 125 crops or crop genepools have been characterized or evaluated for one or more traits. But characterization and evaluation of germplasm is an ongoing process. An individual accession, or an entire collection, can never be considered fully evaluated, as it is only possible to evaluate for known traits. As new diseases or abiotic stresses occur, evaluation for resistance to those stresses must start anew. Although evaluation data for priority traits are important, perhaps the greatest value of a genetically diverse plant germplasm collection is the opportunity it provides to discover new or unknown traits (i.e., resistance to a new disease or a new race of a disease, a quality trait needed for a new processed product, etc.).

Core collections of accessions (Brown *et al*., 1989) have been established for 44 of the NPGS's substantial collections of crops and crop genepools, as an entry point for accessing their range of diversity. For those species or genepools that have an established core collection, accessions in the core are so designated in the GRIN database. In cases in which specific core collections have not been identified, curators have often identified "unofficial" cores or test arrays based on their knowledge of the collection, and they apply that information as they respond to germplasm requests.

The NPGS's role in enhancing plant genetic resources is often limited to supporting actual genetic enhancement or pre-breeding efforts by ensuring that the germplasm it maintains is characterized and evaluated as completely as possible and that the material it distributes is highly viable and true to type. NPGS research priorities for encouraging the use of plant genetic resources in breeding and research include expansion of molecular characterization capabilities at the working and base collections to measure genetic diversity and divergence and to ensure genetic integrity of all accessions. Nonetheless, the paucity of enhancement or pre-breeding research being conducted with many crop genepools may on occasion hamper more effective utilization of genetic resources. Lack of resources is the primary limiting factor for such efforts within the NPGS *per se*. Such programs can help identify valuable traits and elucidate the inheritance of genes controlling those traits, which facilitates their transfer into adapted germplasm. Thus, enhancement efforts may make it easier and more likely that useful genes will be incorporated into applied plant-breeding programs (Trevisan and Blanco, 2008).

Research priorities for germplasm enhancement are under development by individual federal, state, and private programs, or by multi-sectoral collaborations. A notable example of a collaborative enhancement program involving both public and private partners is the Germplasm Enhancement of Maize (GEM) project (http://www.public.iastate.edu/~usda-gem), dedicated to the development of new sources of enhanced maize germplasm. GEM is a diverse collaboration involving nearly 50 domestic and 16 international cooperators that identifies and incorporates favorable alleles for high-priority traits from exotic germplasm into commercially useful genetic backgrounds.

Accessions of NPGS germplasm are requested by public and private-sector scientists of many disciplines for a wide variety of research and breeding projects. For major field crops, such as grain, oilseeds, fiber crops, and some vegetables, private-sector involvement in plant breeding has increased relative to that in the public-sector. A comprehensive survey completed in 1994 (Frey, 1996) of plant breeders in the U.S. public and private confirmed that private industry had assumed a greater role in applied plant breeding and cultivar-development programs for many crops and that USDA and university scientists had shifted towards more basic research, including the development and application of new biotechnological and genomic approaches for plant improvement. There is ongoing discussion and concern about whether universities can continue to provide adequate training for field-based, applied plant breeding research, and for the future of genetic improvement for minor crops, the focus of earlier public research programs.

In 2001, a follow-up survey (Traxler *et al*., 2005) was conducted to determine the number of scientists working on plant-breeding research, genepool enhancement, cultivar development, and plant biotechnology development for field, forage, horticultural, and specialty crops in the U.S. This survey indicated that plant breeding in the U.S. had continued to undergo important changes since 1994, including the widespread incorporation of plant biotechnology into plant-breeding programs. The number of plant breeders employed by universities and state agricultural experiment stations had declined by 21% since 1994. Most plant breeders in the U.S. focused on cereals, followed by grain legumes, but significant changes in the effort devoted to other crop categories occurred from 1994 to 2001. The number of experiment station scientists focusing on forages, leafy vegetables, bulb and stem vegetables, fruit vegetables, root and tuber vegetables, temperate fruit and nut crops, and medicinal, spice and special crops declined 30% or more during those seven years.

During 1994 to 2001, the number of plant breeders employed by the USDA/ARS increased by 23%, and the amount of research devoted to various crops changed significantly. The number of researchers focusing on cereals increased, but fewer scientists were involved in breeding research for the other crop categories. The low response rate from the private sector made it difficult to compare the total number of privately employed plant breeders between survey years and assess the range of crops and types of breeding research they addressed.

The steep decline in national plant-breeding investment in the public sector and the resultant weakening of university plant-breeding education programs during this period led to additional workshops, meetings, and the formation of a National Association of Plant Breeders (see http://www.plantbreeding.org/napb/Publications/Publications.html) which endeavors to strengthen U.S. plant breeding capacity by encouraging improvements in infrastructure, including plant genetic resource conservation.

4.3 Seed-supply systems and the role of markets

To date, the U.S. has not adopted any national strategies to address genetic vulnerability in farming systems, nor are there plans to do so in the future. For the most part, the diversification of crop production in the U.S. is dictated by economics and market forces wherein the buyer or end user of a particular crop might influence the cultivar grown. Also, the farmer or producer has the option to grow for specific end-users (usually via contract) or might sell their crop on the diverse U.S. open market. There are no policy or legal prohibitions that would preclude diversification of crop production and genetic diversity in crops in the U.S.

Seed production and distribution in the U.S. are primarily private-sector functions, but, in some crops, state universities and state crop improvement associations play important roles in transferring technology developed by university and USDA/ARS researchers to the public sector or directly to producers. The sale and distribution of seeds and other propagules to farmers are regulated by national (USDA/Agricultural Marketing Service) and state agencies. Adequate supplies of high-quality seed of a wide range of cultivars of all major and minor crops grown in the U.S. are generally available. Nevertheless, the supply of seed of genetically appropriate native plant materials needed to stabilize, rehabilitate and restore lands damaged by fire, invasive species, and other agents in the U.S. is sometimes limited. The Plant Conservation Alliance, through its working groups, the Native Plant Materials Development Program and the Seeds of Success, is working to collect materials and partner with the seed industry to produce and make them more available.

An extensive national network of seed companies, farm and garden stores, cooperatives, extension personnel and others ensure that the products of publicly and privately funded crop-improvement programs are made available to farmers and gardeners. Cultivars developed by public-sector breeding programs may be released to all interested seed companies to produce and market or may be released exclusively to a single company. Companies sometimes seek an exclusive license before agreeing to market a new publicly developed cultivar in order to ensure a sufficiently large demand for seeds to cover the costs of production and marketing.

Before new cultivars are made available for sale, companies try to ensure that a sufficient quantity of seed (or other propagules) is available to meet the expected demand. In addition to their production facilities in the U.S., seed companies typically also produce seed during the "off-season" in the Southern Hemisphere and/or in subtropical/tropical regions to speed increase of new cultivars and secure a sufficient supply for sale.

The Federal Seed Act and state seed laws govern various aspects of the sale and distribution of seeds in the U.S. Legal requirements for the certification of seed do not exist in the U.S.; and therefore, do not serve as a constraint to distributing traditional cultivars, landraces, or heirloom varieties from NPGS genebanks. Some small seed companies do sell certified seed because it earns them a higher profit for certain crops. Seed certification can be advantageous to small and large seed companies for export markets or organic production systems, especially in crops in which genetic-engineered cultivars are common.

In recent years, there has been an increased consumer interest in the U.S. in locally grown foods, particularly fresh fruits and vegetables. Given the U.S.'s open-market system, national strategies to link producers with markets are generally not necessary because, as the demand for locally grown produce increases, producers respond to meet the demand.

4.4 Crop improvement programs and food security

As indicated previously, crop improvement programs in the U.S. are well established and highly effective for virtually all of the crops grown in the country. Although major crops such as corn, wheat, and soybeans, have had, and continue to have, the greatest attention devoted to them by plant breeders and other scientists, over time many, but not all, major and minor crops grown in the U.S. have benefitted from breeding or crop-improvement programs. U.S. plant breeding programs have many goals and are diverse in their approaches. They conduct research on many of the major crops grown in the country as well as on selected minor crops. Specific procedures employed vary depending on the plant species and project objectives.

The objectives of breeding research range from the introduction of a specific gene or trait into a locally adapted cultivar to the development of a totally new crop plant. The latter usually involves a lengthy and complicated series of crosses and selections of diverse germplasm. A common focus of many of the programs is identifying and incorporating resistance to biotic and abiotic stresses, such as disease and insect resistance and adaptation to a range of different soil and climatic conditions. Emphasis is also usually placed on improving yield potential and quality, taking into account the intended use of the new cultivars.

Increasing crop resistance to pests and diseases has been a longstanding goal of crop improvement programs. The use of plant genetic resources has also contributed significantly to the development of improved cultivars that are high yielding, responsive to improved cultural practices, resistant to environmental stresses, and produce high-quality food, feed or fiber. Plant-breeding research and farmers' utilization of improved cultivars and hybrids have contributed greatly to the fact that the average U.S. family now spends only a minor portion of its income for food. Although it is not possible to assign a precise value to the contribution that plant genetic resources and their use in developing improved cultivars in the U.S. has made to the populations of other countries, it has without question been highly significant. For example, ARS scientists provided the breakthrough crosses in wheat that led to the broad use of the 'Norin 10' dwarf genes in both spring and winter semi-dwarf wheats.

As noted in Chapter 2, farmers in the U.S. are generally not directly involved in the breeding of new cultivars, although they do have opportunities to communicate their needs directly to extension specialists, research scientists, and other representatives of seed or processing companies. Farmers' greatest impact on crop-improvement programs probably results from their influence on markets as they select specific cultivars to purchase and grow.

As pressures mount to develop higher yielding cultivars to feed the world's ever-increasing population, it is anticipated that plant breeding and the use of plant genetic resources will increase in importance. New or unanticipated needs will also arise due to the evolution of diseases and pests and to climate changes. If scientists, and subsequently farmers, are able to meet these challenges, germplasm or plant genetic resources will be the "raw material" that makes it possible. Also, germplasm that has in the past been considered interesting, but of little practical value because it was only distantly related to cultivated crop species, will in all likelihood become much more important as new techniques to transfer genes between species or genera that were previously incompatible are developed and refined.

4.5 State of the art

Public and private plant breeders in the U.S. currently employ a wide variety of breeding methods. Geneticists are attempting to identify and describe the genes and alleles that control complex genetic traits and biological pathways. Informatics, genomics and genetic analysis are being applied to dissect and understand these complex traits. For some crops and certain specific breeding challenges, the methods, techniques, and knowledge developed through genomic research have accelerated the pace of plant improvement and increased the specificity with which plants can be genetically characterized. Time-tested plant breeding approaches that integrate the most effective new techniques will be the cornerstone for genetic improvement of major, specialty, industrial, and other new crops, to the extent that available resources permit.

CHAPTER 5

THE STATE OF NATIONAL PROGRAMS, TRAINING AND LEGISLATION

5.1 National programs

Early in its history, the U.S. government recognized the need for an ongoing search for crops that were adaptable to the diverse growing conditions that existed in the developing country. The history of plant introduction and the early growth and development of what became the U.S. National Plant Germplasm System (NPGS) was reviewed comprehensively by Janick (1989).

In 1990, the U.S. Congress passed legislation (P.L.101-624) that authorized establishment of a National Genetic Resources Program (NGRP) to acquire, characterize, preserve, document, and distribute germplasm of all life forms (i.e., plant, animal, microbial, insect, and aquatic species) important for food and agricultural production. The ARS was assigned the primary role of coordinating and administering the NGRP. In addition, the 1990 legislation directed establishment of a National Genetic Resources Advisory Committee (NGRAC) to respond to the important issues of the nation related to conserving and utilizing genetic resources for food and agriculture. The NGRAC has been inactive since 1999, as other consultative processes have come to the forefront (see below).

Currently within ARS, NPGS activities are a part of the agency's National Program 301 - Plant Genetic Resources, Genomics and Genetic Improvement. The Action Plan for this National Program covers a five-year period, with the most recent for 2008-2013 (see http://www.ars.usda.gov/research/programs/programs.htm?np_code=301&docid=17663). Within this National Program, individual Project Plans are formulated for each specific Research Project, including those that support the individual NPGS genebanks. Prior to development or renewal of the Action Plan for a National Program, a workshop is held in order to obtain input from stakeholders representing a wide variety of public and private research institutions and agricultural producers. The Action Plan then serves as the overall framework for individual Project Plans.

The NPGS is a part of the same ARS National Program as the agency's genomics and genetic-improvement programs. This National Program addresses the need to ensure the long-term safety and integrity of agriculturally valuable genetic-resource collections; to identify favorable alleles and create novel methods to deploy them; to exploit new technologies that enhance traditional methods of genetic improvement; to genetically improve a broad spectrum of major, specialty, and new crops; to increase knowledge of crop genomes; and to acquire, analyze, and deliver genetic and informatics resources to the public. The ARS Office of National Programs ensures that plant genetic resource conservation is coordinated with genomics and genetic-improvement activities.

Funding for the NPGS comes from Federal appropriations and State contributions that include land, laboratory and office space, scientists, and support services. Private industry underwrites selected projects related to germplasm maintenance, regeneration, and evaluation. Industry also plays a major role in the development and transfer of germplasm in the form of improved cultivars to farmers and other consumers, both from its own and from public research programs.

5.2 Networks

During the 1980s, forty Crop Germplasm Committees (CGCs), as described in Chapter 3, were established to provide technical input to the various working components of the NPGS. Two additional CGCs were recently created. These committees serve many functions including analysis of the composition of the NPGS collections, making recommendations and participating in the acquisition of additional germplasm, advising curators on cultural and regeneration procedures, and developing descriptors for germplasm characterization and evaluation.

In addition to the CGCs, there are networks, both formal and informal, of scientists from different disciplines working on virtually every crop or crop group. These include groups such as the National Wheat Improvement Committee, the Tomato Breeders' Roundtable, the American Society of Sugarcane Technologists, the Beltwide Cotton Conference, the Bean and Pea Improvement Conference, the Alfalfa Improvement Conference, and the North American Barley Researchers. These groups usually meet annually, and although their primary focus is not genetic resources *per se*, this subject concerns them and receives attention during their meetings. For many of these groups, the pertinent CGC is considered to serve as a subcommittee that represents the larger group on matters relevant to germplasm conservation and use.

Membership in the various commodity groups, and participation in their meetings, is typically open to anyone interested in the crop and involved in some aspect of research on its improvement or production. In addition to U.S. scientists, members often include scientists from neighboring North American nations and occasionally from more distant nations or International Agricultural Research Centers.

5.3 Education and training

For the most part, the scientific and support staff of the NPGS is adequately trained to carry out its mission. Many NPGS site managers, scientists, and support staff hold advanced degrees awarded by U.S. universities. The specific areas of expertise vary, but include the disciplines of genetics, molecular biology, plant breeding, agronomy, horticulture, plant pathology, plant physiology, plant systematics and evolution, entomology, bioinformatics and information technology.

At present, there are no U.S. universities offering regularly scheduled training or specific courses in plant genetic resource management. However, training in botany, genetics, plant physiology, conservation biology, taxonomy, statistics, and other subjects related to the plant sciences are available at numerous institutions and are helping to meet the needs of the NPGS staff. In most cases, individuals with undergraduate or graduate degrees in one of the agricultural disciplines have taken at least one course in most of the subjects pertinent to plant genetic resource programs.

There are no insurmountable barriers to securing the required education and training for individuals involved in the NPGS. Nevertheless, with cutbacks in university programs, it is increasingly problematic to obtain advanced training in floristics, plant taxonomy and systematics, and field-oriented plant sciences in general. The individual NPGS sites train their employees in the specific requirements for their assigned tasks or positions. NPGS sites also occasionally train employees from other sites and other national genebanks in specific techniques. The relatively low turnover rate of the NPGS staff reflects the interest in and dedication to its mission and reduces the need for new employee training.

5.4 National legislation

Subsequent to the 1990 Farm Bill (mentioned above), no major new legislation specifically focused on plant genetic resources in the U.S. has been enacted at the national level during the subsequent years. National regulations on importing plant germplasm are continually updated by the USDA Animal and Plant Health Inspection Service (APHIS), as necessary to prevent the risk of introducing pests and pathogens not already present in the U.S. Recently, USDA/APHIS has substantially revised its Quarantine 37 (Q37) regulations, resulting in broader and more tightly enforced regulation of incoming plant materials.

In 2002, the United States signed the International Treaty on Plant Genetic Resources for Food and Agriculture. In 2008, the President transmitted the Treaty to the U.S. Senate for advice and consent to ratification. The Senate Foreign Relations Committee held a formal hearing on the Treaty in November 2009. The Senate is now expected to consider further whether to provide its advice and consent to U.S. ratification of the Treaty.

5.5 Information systems

A 1976-77 feasibility study identified the need for a centralized information system for the NPGS. Subsequently, steps were taken to develop a centralized database to manage the passport, inventory, evaluation, characterization, and order processing or distribution data relevant to NPGS collections. Passport data for most of the active accessions that entered the system prior to 1979 were taken from the published Plant Inventory Records and entered into GRIN, although the transfer is not complete for all crops. The recent digitization of many of the Plant Inventory Records will facilitate this task. The amount of indigenous knowledge about the germplasm accessions in the NPGS collection is relatively limited; however, when such knowledge exists, it is included as a part of the collectors' notes in the passport area of GRIN, or in paper copies that have yet to be digitized.

The GRIN database contains an extensive array of characterization and evaluation data for NPGS accessions. Crops that have been most extensively evaluated include wheat, barley, oats, rice, alfalfa, clover, sorghum, maize, potato, sugarbeet, sunflower, soybean, cucumber, and melons. However, as stated in Chapter 4, there are data in GRIN on accessions of more than 125 crops or crop genepools.

Beginning in the 1980s, the GRIN Database Management Unit has regularly obtained input from a diverse range of scientists and germplasm users to develop standard formats for passport data and crop descriptors to facilitate data exchange. This need for expert input on the development of standardized crop descriptors was actually the impetus for the creation of the CGCs.

The information management capabilities of GRIN and associated linked databases have been repeatedly enhanced to take advantage of hardware, software, and communication-system developments and to better manage the dynamic phenotypic and genotypic data that underpin the genetic resource management program.

Building upon GRIN, in 2008, the Global Crop Diversity Trust began to provide funding to USDA-ARS to develop programming for a scalable, open-source information-management system to facilitate management of the world's genebanks. The new system is called GRIN-Global. A technical steering group, composed of international stakeholders, and representatives of the USDA/ARS, the Global Crop Diversity Trust and Bioversity International, helps guide programmatic decisions and ensure that the new system will meet the needs of a diverse group of users. Bioversity International will be responsible for deployment of GRIN-Global internationally. Bioversity International, working through regional networks, its regional offices, and the Consultative Group on International Agricultural Research System-wide Genetic Resources Program, will document GRIN-Global in Arabic, English, French, Russian and Spanish, translate its interface, and implement it in other countries.

5.6 Public awareness

In recent years, there has been a tangible increase in the general public's awareness of the importance of plant biological and genetic diversity. Much of this new awareness has been driven by the recurrent positive publicity associated with the Svalbard Seed Vault in arctic Norway (see http://www.croptrust.org/main/). Nevertheless, there is still relatively limited awareness in the U.S. of the specific role and value of plant genetic resources. Periodic efforts to increase awareness of the existence and importance of plant genetic resources programs continue, but these have resulted in mixed success.

5.7 State of the art

The U.S. scientific community and those involved in various aspects of production agriculture realize that plant genetic resources are the base from which all crop production stems. In recent years, agricultural economists from the USDA Economic Research Service and other institutions have conducted several studies to assess the value of pre-commercial genetic resources, the economics of plant breeding, and the contribution of genetic improvement of crop plants to agricultural productivity and the economy of the U.S. (e.g., Frey, 1996; Smale and Rubenstein, 2002; Traxler *et al*., 2005; Day-Rubenstein *et al*., 2006).

CHAPTER 6

THE STATE OF REGIONAL AND INTERNATIONAL COLLABORATION

6.1 Bilateral and international networks

Scientists and administrators associated with the U.S. and Canadian plant genetic resources programs have a long history of bilateral cooperation on virtually all aspects of genetic resources preservation and utilization. Individuals from these two national programs routinely communicate and participate in each other's technical meetings and advisory committees. Germplasm and data are freely exchanged by the two programs. In addition, the programs periodically cooperate on germplasm preservation activities. A recent example of the latter involves the cryopreservation of 302 *Malus* accessions from the Canadian collection at the National Center for Genetic Resources Preservation in Ft. Collins, Colorado.

In the 1990s, the NPGS provided a copy of the Germplasm Resources Information Network (GRIN) software to the Canadian Genetic Resources Program. Canada then made necessary adaptations to accommodate their specific technical and language needs, and GRIN-CA became their official database. All subsequent updates to GRIN software have been routinely shared with our Canadian counterparts. Utilization of a common information system facilitates germplasm and information sharing, as well as research, in both countries.

Complementing cooperation between the national germplasm preservation programs, Canadian and U.S. scientists involved in breeding and other types of plant research frequently enjoy close cooperation. Several Canadian scientists are members of NPGS Crop Germplasm Committees and the crop improvement organizations described in Chapter 4.

During the 1990s, the Organization of American States, Inter-American Institute for Cooperation on Agriculture (IICA), created several networks for cooperation in plant genetic resources activities within the Americas. Among these is NORGEN, the Plant Genetic Resources Network for PROCINORTE (Cooperative Program in Agricultural Research and Technology for the Northern Region), which was created to stimulate formal cooperation among Canada, Mexico and the U.S. Since October 1999, representatives from the three nations have met regularly. NORGEN strives to identify common problems and opportunities that permit the development of coordinated actions among institutions with responsibility for genetic resources in Canada, Mexico, and the U.S. to promote the conservation and sustainable use of plant genetic resources. NORGEN's specific objectives involve sharing information, development of cooperative projects, capacity building, training, and integration of activities with other genetic resources networks within the Americas and around the world. Recent NORGEN activities include a joint U.S., Canada, and Mexico genetics and breeding project on dry beans (*Phaseolus*), and training of Canadian and Mexican genebank personnel in the new GRIN-Global germplasm information system (see details above, and also the website (http://www.procinorte.net/Pages/Genetic%20Resources%20Task%20Force.aspx).

6.2 International programs

Beginning in the 1980s and continuing in the 1990s, the NPGS benefitted from collaborations with the International Board for Plant Genetic Resources (IBPGR) and its successor organization, the International Plant Genetic Resources Institute (IPGRI), on plant exploration and collection. IBPGR paid the salary and expenses of a scientist located with the GRIN/DBMU to assist in the documentation of germplasm collected during IBPGR and IPGRI-supported explorations.

IPGRI has now evolved into Bioversity International. Currently, primary collaborations between ARS and Bioversity involve development of the GRIN-Global genetic resource information management system (see above), and encouraging the development of CacaoNet, a "virtual" international genebank for cacao germplasm accessions held in international and national research centers primarily in Latin America (see https://sites.google.com/a/cgxchange.org/cacaonet/news/cacaonetconservationstrategy).

The U.S. government, through the U.S. Agency for International Development (USAID), provides financial support to the Consultative Group on International Agricultural Research (CGIAR) system, including the 15 International Agricultural Research Centers (IARCs). Funds are provided both as core support to the system and to targeted research and information dissemination efforts. USAID support for the CGIAR is an important component of the U.S. Government's comprehensive approach to improving global food security. Since 2002, the U.S. government through USAID has provided $14.5 million to the endowment of the Global Crop Diversity Trust. Another $10 million was pledged in 2010.

The U.S. government has also provided funds to several projects that support germplasm conservation and use in specific countries. NPGS scientists have collaborated with the USDA/Foreign Agricultural Service (FAS) and the USDA/ARS Office of International Research Programs on these projects. In India, a project at the National Bureau of Plant Genetic Resources Regional Station at Thrissur, Kerala, developed a tissue-culture facility, installed field irrigation in a newly developed area, purchased a medium-term, seed-storage unit, and supported seed increases and characterization of eggplant germplasm. In Bangladesh, scientists at the Bangladesh Agricultural University in Mymensing, collected, evaluated, preserved and distributed germplasm of landraces and wild relatives of traditional fruits and vegetables. Eleven projects at the Plant Genetic Resources Centre in Sri Lanka were supported for the collection and evaluation of crop wild relatives, training staff in advanced research techniques and maintenance of genebank facilities and equipment, and purchasing research equipment and supplies. In Armenia, two institutes received funding to develop medium-term seed storage facilities.

In Ecuador, the Plant Exchange Office (PEO) collaborated with the National Department of Genetic Resources and Biotechnology of the National Institute of Agricultural Research, Bioversity International, and USDA/FAS on a six-year, P.L. 480-funded project to support complementary (*ex situ* and on-farm) conservation and increased utilization of agrobiodiversity in native farming communities in Cotacachi, Ecuador. Native landraces were documented, conserved in the national genebank, and characterized in cooperation with farmers. Numerous initiatives strengthened farmers' capacity and opportunity to conserve this diversity on-farm, including the establishment of a food-processing plant to develop and package products made from local crops, seed exchange fairs, and promotion of agrotourism. Knowledge and use of traditional crops in the communities were reinforced though workshops, development of educational programs for schools, and establishment of a community-run ethnobotanical garden.

Funding from USDA's international assistance programs provided $1 million for a project in Peru, which was developed by USDA-ARS and FAS in cooperation with of the Sub-Directorate of Genetic Resources and Biotechnology of the National Institute of Agricultural Research and Extension (INIEA), which has the responsibility for the Peruvian national genetic resources program. Major structural renovation and remodeling were carried out on the seed-conservation laboratory, cold-storage facility, molecular-biology laboratory, *in vitro* conservation laboratory and propagation greenhouse, offices, and library. Facility and equipment upgrades were provided to nine INIEA experiment stations with field germplasm collections. In addition, the germplasm-documentation system was updated, existing collections were inventoried and documented, and crop collections were re-organized and backed up in long-term storage.

In Guyana, with funding from USDA/FAS, the facilities of the Department of Plant Biotechnology and Genetic Resources of the National Agricultural Research Institute (NARI) were upgraded, and training of scientists at U.S. laboratories and at the NARI headquarters was provided. A molecular-biology laboratory was equipped and a screenhouse renovated. A four-wheel drive vehicle, computers, and high-speed DSL Internet equipment were purchased. Field genebanks of coconut, mango, avocado, and cassava were established at three NARI experiment stations. In addition, workshops on national access and benefit sharing legislation were held with participation of many stakeholders in Guyana.

Finally, in January 2008, the NPGS sent seeds of approximately 11 000 accessions, including nearly 1 500 that originated in the U.S., to the Svalbard Global Seed Vault in Norway for long-term preservation. In 2009 and 2010, more than 11 000 additional accessions were sent. It is anticipated that additional accessions will be sent to Svalbard in future years.

6.3 International agreements

The U.S. signed the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), and the Senate is currently considering it for ratification (see details above). Although the U.S. has not ratified the Treaty, the NPGS has consistently taken into account its provisions and those of the Convention on Biological Diversity. The NPGS staff has developed a standard operating procedure for handling incoming germplasm accompanied by the Standard Material Transfer Agreement (SMTA) of the ITPGRFA. All incoming accessions accompanied by the SMTA are documented in GRIN. Recipients of NPGS accessions covered by the SMTA can accept the SMTA on-line through the GRIN order module, by email, or by post. Information regarding distribution of material covered by the SMTA enables the U.S. to fulfill the SMTA reporting requirements to the Governing Body of the ITPGRFA.

During the period from 2000 to 2009, the NPGS entered into arrangements with 33 countries to cooperate in the collection and preservation of plant genetic resources. Some examples include collaborations involving the PEO, the USDA/FAS, and the USDA/ARS Office of International Research Programs to develop joint germplasm collection, conservation and maintenance programs in Jordan, Morocco, Tunisia, Bangladesh, Sri Lanka, Uzbekistan, Pakistan, Kazakhstan, Guyana, Georgia and Azerbaijan. In addition, the PEO has collaborated with the plant genetic resources programs of eight countries in the Caucasus and Central Asia: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, Armenia, Georgia and Azerbaijan through a program organized by International Center for Agricultural Research in the Dry Areas.

As a courtesy to foreign counterparts, the NPGS has provided cold-storage security-backup space for germplasm accessions from foreign national and CGIAR genetic resources programs. In these instances, contractual Cooperative Agreements have been established with several national and IARC genetic resources programs to store duplicate samples of their germplasm collections at the NCGRP in Ft. Collins, Colorado. Depending on the terms of the agreement, the packages containing the accessions may be kept sealed during their storage or the material may be shared for research purposes.

CHAPTER 7

ACCESS TO PLANT GENETIC RESOURCES AND SHARING OF BENEFITS ARISING OUT OF THEIR USE, AND FARMERS' RIGHTS

7.1 Access to plant genetic resources

There are no overall national regulations in the United States governing all access to genetic resources *in situ*. Access is controlled by the landowners, who may be federal, state, county, tribal, or private entities. Permit requirements for the different entities vary widely. During the last ten years, the U.S. has continued to maintain a policy of providing users unrestricted access to all public germplasm held in NPGS genebanks.

During the past ten years, NPGS curators and scientists from the U.S. public and private user communities have frequently experienced difficulties in gaining access to plant genetic resources located outside the U.S. Obstacles have included the inability or unwillingness of foreign national authorities to process applications for access to germplasm requested for collection, requests by foreign national authorities for restrictions on future use or distribution of germplasm that are not consistent with USDA policies, and the complete lack of a response from foreign curators or national authorities to U.S. requests for access to germplasm.

7.2 Fair and equitable sharing of the benefits of the use of plant genetic resources

The U.S. advocates enlisting all available means to preserve plant genetic resources and make them available for use. If germplasm is not available for use by parties with the interest and capability to identify and deploy valuable traits, that germplasm will accrue no benefits. If owners of germplasm lack the requisite resources, the interest, or the commitment to conserve or utilize germplasm, it is important for humanity that they permit others to protect or preserve the material to ensure that it not be lost.

As described in Chapter 4, the availability of, and access to, germplasm by scientists from the public and private sectors have resulted in hundreds of examples of its use to improve most of the crop plants grown in the U.S. Since the earliest attempts to breed improved plants, plant genetic resources have served as the raw material for the development of improved cultivars that are resistant to diseases, insect pests and environmental stresses, high yielding, responsive to improved cultural practices, and possess quality attributes that make them desirable for food, feed, fiber, and industrial uses. Plant breeding research and farmers' utilization of the resulting improved cultivars have contributed immensely to the fact that the average U.S. family now spends only a minor portion of its household income for food.

All segments of the U.S. population share in the benefits arising from the use of plant genetic resources. Farmers benefit by having access to modern cultivars that possess many traits, such as pest resistance and efficient biomass partitioning, that make it possible for them to consistently produce high yields of desired crops, while more efficiently using water and nutrients and reducing pesticide use. The preceding traits are vital for farmers to remain profitable. Livestock producers benefit by having a plentiful supply of nutritious feed for their livestock. Companies that process and/or market seeds and agricultural commodities for food or industrial uses have access to consistent supplies of marketable products. Consumers often receive the most substantial benefits from a bountiful supply of wholesome food and other agricultural products available at a reasonable cost.

To assess the benefits arising from the use of genetic resources in today's world from a broader perspective, one must look beyond national borders and interests. Increasingly, cultivars available to U.S. farmers are developed by multinational companies that distribute the same cultivars in numerous countries. Even if the same cultivars are not marketed in other countries, the same germplasm (or parental lines developed from it) will very likely contribute to the pedigrees of cultivars adapted to other areas. If they incorporate traits that are valuable beyond a local region, improved cultivars developed by universities, government agencies or local companies also typically find their way into global usage, as parental lines in breeding programs or as cultivars *per se*. Beyond the role of plant genetic resources in breeding new cultivars, the genetic diversity of germplasm and its unique traits are often critical to generating basic information and new techniques that can transform future agricultural production. Thus, there is often valuable "technological spillover" from the ready access to genetic diversity and associated characterization and evaluation data.

Typically much time and effort must be spent to identify, determine the utility, and determine the value of germplasm before it is possible to assign a fair and equitable monetary value to it. In the U.S., the existing legal system accommodates issues regarding intellectual property rights and ownership of private property related to plant genetic resources. It is common practice for private companies, as well as for universities and other public agencies, to negotiate mutually agreeable terms or arrangements regarding benefit-sharing prior to sharing or exchanging material that has resulted from plant breeding and/or genetic enhancement.

7.3 Implementation of farmers' rights

The U.S. recognizes the importance of farmers' rights and promotes them pursuant to various national and state laws, regulations and orders, including contract law, unfair competition laws, intellectual property laws, and Executive Order 13175 (November 6, 2000) "Consultation and Coordination with Indian Tribal Governments." Further, the USDA has long conveyed extensive non-monetary benefits to farmers through land grant universities and extension services authorized under, inter alia, 7 U.S.C. 301 et seq., and 341 et seq. The USDA also provides services specifically to indigenous communities through, inter alia, Title V of PL-103-382 (Oct. 20, 1994); Title XVI, 1677, PL-101-64 (1990 Farm Bill); U.S.C. 3241 and 20 U.S.C. 1059d.

CHAPTER 8

THE CONTRIBUTION OF PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE (PGRFA) MANAGEMENT TO FOOD SECURITY AND SUSTAINABLE DEVELOPMENT

The crucial role that plant genetic resources play in agricultural sustainability, food security, economic development and poverty alleviation has been well documented (see Literature Cited for examples). Its importance will not diminish in the future and in all likelihood will increase (e.g., Day-Rubenstein et al. 2006). Genetic diversity must be preserved for current and future use, but simple preservation is not enough. If germplasm is not readily available for use, resources expended to preserve it will be wasted. Although nations must ultimately be responsible for their own specific needs, issues regarding germplasm must be resolved on a global scale, because no country is self sufficient in crop genetic resources. Nations with PGRFA that exist naturally within their borders should recognize the pressing need to cooperate and contribute according to their own national capacities. Ideally, barriers to the global sharing of germplasm and associated data would be reduced or disappear.

In particular, a coordinated effort is critical to collect and preserve the wild crop relatives and genebank collections that exist globally. Although preserving farmers' varieties and landraces is extremely important, the wild relatives of our crop plants are more likely to contain the genes essential for the next major advances in crop improvement needed to sustain an ever-growing human population.

Studies of the value of PGRFA and its role in human affairs (e.g., Esquinas-Alcázar, 2005; Qualset and Shands, 2005) collectively constitute a thorough exploration of the nexus between PGRFA and humanity. Thus, a high priority should be assigned to communicating to a broader audience our current understanding of the roles and values (economic, cultural, and ecological) associated with PGRFA within individual nations, and globally. Without widespread recognition of the critical role of PGRFA in human survival and well-being, political and, subsequently, fiscal support for PGRFA conservation and sustainable use will inevitably erode.

Fortunately, since the first State of the World Report, the Internet has revolutionized global communication. Information can be transmitted rapidly to a much broader audience more efficiently, effectively, and at less expense. Rough translations among languages can be completed by automated translation programs within seconds. Telecommunication has become more reliable and less expensive. For example, many people viewed the opening of the Svalbard Seed Vault (see http://www.croptrust.org/main) "live" through the Internet, and online stories about this critical new facility reverberated throughout printed and broadcast media for many months thereafter, and continue to reverberate throughout "cyberspace." But, with access to so much information, transmitting this "message" will not be enough, because the global media present new crises every day. The roles and values of PGRFA must be re-emphasized repeatedly in many different forms, year in, year out, until the critical priority for PGRFA conservation and sustainable use is soundly understood and appreciated worldwide.

REFERENCES CITED

Bretting, P.K. and Duvick, D.N. 1997. Dynamic conservation of plant genetic resources. Adv. Agron. 61:1-51.

Brown, A.H.D., Frankel, O.H., Marshall, D.R. and Williams, J.T. (eds.). 1989. The use of plant genetic resources. Cambridge University Press, Cambridge, United Kingdom.

Day-Rubenstein, K., Smale, M. and Widrlechner, M.P. 2006. Demand for genetic resources and the U.S. National Plant Germplasm System. Crop Sci. 46:1021-1031.

Engels, J.M.M., Rao, V.R., Brown, A.H.D. and Jackson, M.T. (eds.) 2002. Managing plant genetic diversity. CABI Publishing, Oxon, United Kingdom, and New York.

Esquinas-Alcázar, J. 2005. Protecting crop genetic diversity for food security: political, ethical and technical challenges. Nat. Rev. Genet. 6:946-952.

Fowler, C. and Hodgkin, T. 2004. Plant genetic resources for food and agriculture: assessing global availability. Annu. Rev. Environ. Resour. 29:143-179.

Frey, K.J. 1996. National Plant Breeding Study-I. Human and Financial Resources devoted to Plant Breeding Research and Development in the United States in 1994. Special Report 98, Iowa Agriculture and Home Economics Experiment Station, Ames. IA.

Heywood, V.H. and Dulloo, M.E. 2005. *In situ* conservation of wild plant species: A global review of good practices. International Plant Genetic Resources Institute (IPGRI) Technical Bulletin 11. IPGRI, Rome.

Janick, J. (ed.) 1989. The National Plant Germplasm System of the United States. Plant Breeding Reviews Vol. 7. Timber Press, Portland, OR.

Mornhinweg, D. W., Bregitzer, P.P., Porter, D.R., Peairs, R.B., Baltensperger, D.D., Hein, G.L., Randolph, T.A., Koch, M. and Walker, T. 2009. Registration of 'Sidney' spring feed barley resistant to Russian Wheat Aphid. J. of Plant Registrations 3(3):214-218.

Novy, R.G., Love, S.L., Corsini, D.L., Pavek, J.J., Whitworth, J.L., Mosley, A.R., James, S.R., Hane, D.C., Shock, C.C., Rykbost, K.A., Brown, C.R., Thornton, R.E. , Knowles, N.R., Pavek, M.J., Olsen, N., and Inglis, D.A. 2006. Defender: A high-yielding, processing potato cultivar with foliar and tuber resistance to late blight. American Journal of Potato Research 83:9-19.

Postman, J., Hummer, K., Stover, E., Krueger, R. Forsline, P., Grauke, L.J., Zee, F., Ayala-Silva, T. and Irish, B. 2006. Fruit and nut genebanks in the U.S. National Plant Germplasm System. HortScience 41:1188-1194.

Qualset, C.O. and Shands, H.L. 2005. Safeguarding the future of U.S. agriculture: the need to conserve threatened collections of crop diversity worldwide. University of California, Division of Agriculture and Natural Resources, Genetic Resources Conservation Program, Davis, California. Available online at http://www.grcp.ucdavis.edu/publications/docSafeAg/SafeguardingFutureUSAg.pdf (verified on June 15, 2011)

Safrin, S. 2004. Hyperownership in a time of biotechnological promise: the international conflict to control the building blocks of life. Amer. J. Intl. Law 98 L.641. 53 pp.

Scholl, R., Sachs, M.M. and Ware, D. 2003. Maintaining collections of mutants for plant functional genomics. p. 311-326. In: Grotewald, E. (ed.), Methods in Molecular Biology, Vol. 236, Plant Functional Genomics: Methods and Protocols. Humana Press, Totowa, New Jersey.

Secretariat of the Convention on Biological Diversity. 2002. Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of the Benefits Arising out of their Utilization. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

Shands, H.L. and Wiesner, L.E. 1991. Use of Plant Introductions in Cultivar Development: Part 1. CSSA Special Publication 17, Crop Science Society of America, Madison, Wisconsin.

Shands, H.L. and Wiesner, L.E. 1992. Use of Plant Introductions in Cultivar Development: Part 2. CSSA Special Publication 20, Crop Science Society of America, Madison, Wisconsin.

Smale, M. and Day-Rubenstein, K. 2002. The demand for crop genetic resources: international use of the U.S. National Plant Germplasm System. World Development 30:1639-1655.

Spooner, D., van Treuren, R., and de Vincente, M.C. 2005. Molecular markers for genebank management. IPGRI Technical Bulletin 10. International Plant Genetic Resources Institute, Rome, Italy.

Tay, D., Widrlechner, M.P., and Corfield, J.L. 2004. Establishment of a new genebank for herbaceous ornamental plants. FAO/IPRGI Plant Genetic Resources Newsletter 137:26-33.

Traxler, G., Acquaye, A.K.A., Frey, K., and Thro, A.M. 2005. Public Sector Plant Breeding Resources in the US: Study Results for the year 2001. Available online at http://www.csrees.usda.gov/nea/plants/pdfs/plant_report.pdf (verified on April 12, 2011)

Trevisan, W. and Blanco, M.H. 2008. The Importance of the Germplasm Enhancement of Maize Project (GEM) for US Seed Companies. p. 9-15. In: 44th Annual Illinois Corn Breeders School Proceedings, March 3-4, 2008, Urbana-Champaign, Illinois.

USDA. 2009. 2007 Census of Agriculture. Available online at http://www.agcensus.usda.gov/index.asp (verified on April 12, 2011)

Williams, K.A. 2005. An overview of the U.S. National Plant Germplasm System's exploration program. HortScience 40:297-301.

CONTRIBUTORS

Name	Institution	Email
Peter K. Bretting	USDA-ARS Office of National Programs, Beltsville, Maryland	Peter.Bretting@ars.usda.gov
Allan K. Stoner	USDA-ARS retired	
Mark P. Widrlechner	USDA-ARS North Central Regional Plant Introduction Station, Ames, Iowa	Mark.Widrlechner@ars.usda.gov
Karen A. Williams	USDA-ARS National Germplasm Resources Laboratory, Beltsville, Maryland	Karen.Williams@ars.usda.gov