United States General Accounting Office

GAO

Report to Congressional Committees

October 1997

U.S. DEPARTMENT OF AGRICULTURE

Information on the Condition of the National Plant Germplasm System

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-277794

October 16, 1997

Congressional Committees

This report provides information on the U.S. Department of Agriculture's National Plant Germplasm System. This system provides germplasm that is used by plant breeders and researchers to develop new and improved plant varieties for crop production. To conduct our work, we surveyed the members of the 40 Crop Germplasm Committees that advise the Department on the acquisition, preservation, and information needs of the germplasm collections.

We are sending copies of this report to interested congressional committees; the Secretary of Agriculture; and the chairmen of the 40 germplasm committees surveyed. We will also make copies available upon request.

If you or your staff have any questions, please call me at (202) 512-5138. Major contributors to this report are listed in appendix V.

Robert A. Robinson
Director, Food and
Agriculture Issues

Congressional Committees

The Honorable Richard G. Lugar
Chairman
The Honorable Tom Harkin
Ranking Minority Member
Committee on Agriculture, Nutrition, and Forestry
United States Senate

The Honorable Mitch McConnell
Chairman
The Honorable Patrick J. Leahy
Ranking Minority Member
Subcommittee on Research, Nutrition, and General Legislation
Committee on Agriculture, Nutrition, and Forestry
United States Senate

The Honorable Robert F. (Bob) Smith
Chairman
The Honorable Charles W. Stenholm
Ranking Minority Member
Committee on Agriculture
House of Representatives

The Honorable Larry Combest
Chairman
The Honorable Calvin M. Dooley
Ranking Minority Member
Subcommittee on Forestry, Resource Conservation, and Research
Committee on Agriculture
House of Representatives

Executive Summary

Purpose

The U.S. agricultural sector—renowned for its productivity—owes much of its success to a continuing flow of improved crop varieties that produce higher yields and better withstand pests, diseases, and extreme climates. The genes necessary for these crops are contained in plant germplasm—the material in seeds or other plant parts that controls heredity. To maintain high levels of agricultural productivity, plant breeders need access to an ample supply of germplasm with diverse genetic characteristics.

The U.S. Department of Agriculture's (USDA) National Plant Germplasm System (NPGS) maintains germplasm collections for over 85 crops at sites nationwide. Forty Crop Germplasm Committees (CGC) provide technical advice and guidance to NPGS on germplasm activities. The CGCs are composed of crop experts, including the NPGS curators who are responsible for maintaining and preserving the collections.

Because of the importance of germplasm to U.S. agricultural productivity and food security, GAO surveyed the 680 members of the 40 CGCs for their views on the sufficiency of NPGS' principal activities—(1) acquiring germplasm to ensure the diversity of the collections in order to reduce crop vulnerability, (2) developing and documenting information on germplasm, and (3) preserving germplasm.

Background

NPGS is primarily a federally and state-supported effort aimed at maintaining supplies of plant germplasm with diverse genetic traits for use in breeding and scientific research. The diversity in germplasm collections enables breeders to develop improved crops that are more productive and often less vulnerable to pests and diseases. These collections are particularly important because the diversity of germplasm worldwide has been reduced by several factors, such as the widespread use of genetically uniform crops in commercial agriculture and the destruction of natural habitats that have been important sources of germplasm.

The Agricultural Marketing Act of 1946 established the main components of NPGS as well as a legal basis for federal and state cooperation in managing plant genetic resources. NPGS' current organizational structure—a geographically dispersed network of germplasm collections administered primarily by USDA's Agricultural Research Service (ARS)—emerged in the early 1970s. NPGS maintains about 440,000 germplasm samples for over 85 crops at 22 sites throughout the country and in Puerto Rico; almost half of these samples are maintained at four regional plant introduction stations. Germplasm samples are held in crop collections, each of which generally includes four types of germplasm (for example, germplasm from cultivated plants and germplasm from wild relatives of cultivated plants). Each type of germplasm contains genetic material that plays an important role in the collections' overall diversity.

Most of NPGS' germplasm is imported from other countries and must comply with U.S. quarantine regulations, which are intended to prevent the introduction of pests and pathogens into the United States. Germplasm collections are also maintained by other countries and international organizations, as well as by U.S. and foreign universities and private companies. These collections vary considerably in terms of the quality of preservation, and only some are freely available to breeders.

Although ARS provides the lion's share of support for NPGS, the system is also supported by the states. Private industry also funds selected NPGS projects and transfers germplasm to the public in the form of new plant varieties and hybrids. In fiscal year 1996, NPGS' total funding was $23.3 million, $19.5 million of which was provided by ARS. From fiscal years 1992 through 1996, ARS' funding of NPGS has declined by 14 percent, in constant dollars, while the total size of the collections has increased by 10 percent.

Results in Brief

Just over half of the Crop Germplasm Committees reported that the genetic diversity contained in the National Plant Germplasm System's collections is sufficient to reduce the vulnerability of their crops. Considering both this collection and all other freely available collections, almost three-quarters of the committees said that the diversity in these collections is sufficient for reducing their crops' vulnerability. At the same time, the committees identified several concerns affecting the diversity of their collections, and they ranked the acquisition of germplasm as the highest priority for the germplasm system if more funding becomes available. Current acquisition efforts are hindered by problems in obtaining germplasm from some countries and by USDA's management of the quarantine system, which has contributed to the loss of germplasm and delays in its release for certain plants.

According to the crop committees, many of the system's collections lack sufficient information on germplasm traits to facilitate the germplasm's use in crop breeding. Officials of the germplasm system acknowledged that some information on plant traits, such as resistance to disease or plant structure, either has not been developed or has not always been entered into the system's database. In some cases, the information has not been developed because it is considered to be a lower priority than preserving germplasm; in other instances, the information has been developed by scientists outside of the system and has not been provided for entry into the database.

Preservation activities—viability testing, regeneration, and the long-term backup storage of germplasm—have not kept pace with the preservation needs of the collections. Only minimal viability testing—testing the seeds in a sample to determine how many are alive in order to prevent the loss of the sample—has occurred at two of four major locations. In addition, the system has significant backlogs for regenerating (that is, replenishing) germplasm at the four major locations. Finally, over one-third of the system's germplasm is not stored in the system's secure, long-term storage facility, thereby increasing the risk that samples located around the nation could be lost through environmental damage or other catastrophes.

Principal Findings

Importance of Increasing Diversity Underscored, but Some Obstacles Hinder Acquisition

Over half of the CGCs reported that the genetic diversity of NPGS' collections for their crops is sufficient to reduce crop vulnerability. Moreover, when all freely available collections (including NPGS') were considered, almost three-fourths of the CGCs reported that the collections—including those for many major crops—are sufficiently diverse. Nonetheless, the acquisition of germplasm was viewed as NPGS' top priority—out of 14 germplasm-related activities—in the event of additional funding. Many CGCs identified concerns affecting the diversity of their collections that may contribute to the importance they place on increased acquisition. These include inadequate diversity in one or more of the four types of germplasm making up the collections and the potential loss of germplasm that is at risk in nature.

Although CGCs want to acquire more germplasm, difficulties with some countries prevent such acquisition. Furthermore, the Convention on Biological Diversity has the potential to restrict NPGS' acquisition of germplasm if its signatories make the germplasm subject to certain restrictions that are inconsistent with NPGS' policy.

The acquisition of germplasm has also been hampered by USDA's management of the quarantine process, which has contributed to the loss or delayed release of certain germplasm. Thirteen CGCs, most of whose germplasm often undergoes more intensive scrutiny in quarantine, reported that quarantine regulations and processes have resulted in delays in the timely release of germplasm; 5 CGCs reported problems with the release of viable germplasm. CGCs for crops such as prunus (e.g., cherry and peach trees), apples, pears, potatoes, and corn were among those reporting quarantine-related problems.

Germplasm Information Is Reported to Be Insufficient

Most CGCs reported that NPGS' germplasm collections for their crops lack important information on germplasm traits needed for crop breeding. Breeders need such information to select germplasm with the traits they are seeking from the myriad of germplasm samples. Specifically, three-quarters of the CGCs reported insufficiencies with evaluation information, which describes traits, such as resistance to disease and yield, that are of particular interest to plant breeders. Furthermore, almost half found insufficiencies in characterization information, which describes traits, such as color and plant structure, that are little influenced by the environment. On the other hand, most CGCs reported that passport information is sufficient for crop-breeding purposes. Passport information describes, among other things, the site of origin of the germplasm.

Some evaluation and characterization information has not been developed and entered into NPGS' database for a number of reasons. These reasons include the large amount of germplasm that needs to be evaluated and characterized, the resource-intensive nature of these activities, and limited resources. In addition, most evaluations of NPGS' germplasm are conducted by scientists outside of NPGS—often university and other ARS scientists—who do not always provide NPGS with the resulting information for entry into the database. CGCs estimated that, on average, 50 percent of the useful evaluation information relating to their NPGS collections is not in the database. Characterization information, on the other hand, is primarily developed by NPGS' curators. However, NPGS officials said that characterizing germplasm is generally a lower priority than preserving it. Unlike evaluation and characterization information, passport information should be provided when a sample is donated to NPGS. However, many samples lack some passport information, largely because donors do not always have or provide the information.

Preservation Activities Have Not Kept Pace With the Collections' Needs

Preservation activities—including viability testing, regeneration, and secure, long-term backup storage of germplasm—have not kept pace with the preservation needs of NPGS' collections. Two major NPGS sites, accounting for over one-quarter of the active collections, do not conduct sufficient viability testing to determine the quantity of viable seeds, according to NPGS data and officials. Viability testing should generally be conducted every 5 to 10 years at these sites, depending on the type of plant and storage conditions, according to the site managers. However, in 10 years, the two sites have tested less than one-fourth of their germplasm.

Furthermore, NPGS has significant backlogs of germplasm requiring regeneration—growing the seeds in order to produce a sufficient supply of viable germplasm. For example, at one site that distributes a wide variety of germplasm, about half of its over 60,000 samples required regeneration, and one collection could take as much as 75 years to regenerate, given the current level of resources. NPGS officials said that limited staff resources were the biggest problem contributing to these backlogs.

Finally, only 61 percent of NPGS' approximately 440,000 seed samples are backed up in the system's secure, long-term storage facility, designed to minimize the loss of germplasm viability. A primary reason for the lack of backup is that sites do not provide germplasm to this facility when a germplasm sample has too few seeds. In such instances, the sample must be regenerated before it can be backed up. Furthermore, as of August 1997, NPGS' secure, long-term facility had a 16-month backlog of about 27,000 samples that have to be tested for viability before being placed in permanent, long-term storage.

Recommendations

GAO is making no recommendations in this report.

Agency Comments

GAO provided a draft of this report to USDA for review and comment. USDA did not take issue with any of the information in the report. USDA noted that while NPGS has made large strides since earlier reviews conducted by GAO and the National Research Council, its successes have been dwarfed by its increasing responsibilities in the face of declining resources. USDA stated that unless NPGS' funding is augmented, the system will need to juggle its multiple, sometimes divergent, priorities by making incremental progress in addressing an exceptionally broad range of user demands. In addition, USDA said that the Department would continue to work with other agencies and the private sector to ensure that NPGS is managed effectively. USDA included an attachment to its comments highlighting the progress made since 1990 in addressing NPGS' managerial goals.

GAO appreciates the challenges that NPGS faces in juggling its multiple priorities and managing its increasing collections in the face of declining resources. In that regard, GAO supports USDA's efforts to improve the management of NPGS to make the most effective use of its limited resources. GAO believes that the information provided in this report will assist congressional and other decisionmakers in future deliberations on the role of NPGS and the resources available to NPGS for carrying out its role. Appendix IV contains the complete text of USDA's comments and GAO's response.

Contents

Appendixes

Tables

Figures

Abbreviations

APHIS	Animal and Plant Health Inspection Service
ARS	Agricultural Research Service
CGC	Crop Germplasm Committee
GRIN	Germplasm Resources Information Network
NGRL	National Germplasm Resources Laboratory
NPGS	National Plant Germplasm System
NSSL	National Seed Storage Laboratory
USDA	U.S. Department of Agriculture

Introduction

The U.S. agricultural sector—renowned for its productivity—owes much of its success to a continuing flow of improved crop varieties that produce higher yields and better withstand pests, diseases, and climate extremes. The genes necessary for these improved crops are contained in plant germplasm—the material in seeds or other plant parts that controls heredity. To maintain a high level of agricultural productivity, plant breeders need access to an ample supply of germplasm with diverse genetic characteristics so that they can continue to develop plant varieties that will provide increased yields and better resist pests, diseases, and environmental stresses. However, the diversity of germplasm available to present and future generations of breeders has been reduced by several factors, including the widespread use of genetically uniform crops in commercial agriculture and the destruction of natural habitats, such as forests, that have been important sources of germplasm.

In the United States, the National Plant Germplasm System (NPGS), primarily administered by the U.S. Department of Agriculture (USDA), maintains germplasm collections for over 85 crops at 22 sites nationwide and in Puerto Rico. These collections contain numerous germplasm samples[1] and provide breeders with access to germplasm with a broad range of genetic traits. In addition to maintaining the collections, NPGS is responsible for acquiring germplasm, developing and documenting information that describes the germplasm in the collections, and distributing germplasm to plant breeders and other users in the United States and worldwide.

Germplasm Collections Are Critical to Agricultural Productivity, Food Security, and Biodiversity

Germplasm collections are an important source of genetic material for plant breeders targeting specific traits, such as higher yield, increased resistance to disease and pests, good taste, improved nutritional quality, and environmental and climatic hardiness. To be of greatest use, these collections need to be genetically diverse, thereby giving breeders more possibilities to find the traits they need to develop improved crop varieties. In addition, information on germplasm traits and other related information (e.g., site of origin of the germplasm) should be obtained and documented, and the germplasm must be adequately preserved to be of optimal use to potential users.

[1]A germplasm sample (sometimes referred to as an accession) is a distinct, uniquely identified sample of seeds or plants that is part of a germplasm collection.

Diverse germplasm has played a key role in increasing food security through enhanced crop productivity and reduced crop vulnerability to pests and diseases. For example:

- According to a survey on the use of germplasm in 18 crops grown in the United States from 1976 to 1980,[2] from 1 percent (sweet clover) to 90 percent (sunflower and tomato) of the crop varieties had been improved in part by the use of germplasm from wild relatives of the cultivated crops.
- The high productivity of modern wheat—resistant to many pests, diseases, and other stresses—results from combining germplasm from various varieties of wheat grown around the world to create improved wheat varieties. For example, one well-known germplasm sample from Turkey has been a source of resistance for three different types of disease—common bunt, stripe rust, and snow mold. This germplasm also has the ability to establish vigorous seedlings in hot, dry soils that deter the emergence of many other varieties.[3]
- Most of the genes for insect and disease resistance in tomatoes come from a related wild species[4] that originated outside of the United States. Germplasm from wild species is also a source of tolerance to environmental stress, such as drought. In particular, the discovery of resistance to a soil-borne organism known as the root-knot nematode has made the difference between growing or not growing tomatoes in many subtropical areas of the United States (such as southern California and Florida).

In addition to providing a source of genetic diversity for plant breeders, germplasm collections serve as an archive for rare and endangered crop species. The loss of biodiversity worldwide has made the need for these collections all the more compelling. Expanding human populations, urbanization, deforestation, destruction of the environment, and other factors threaten many of the world's plant genetic resources. These resources are vital to the future of agricultural productivity and the world's food security. Many national and international collections have been established to rescue and conserve these resources for future use.

[2]Managing Global Genetic Resources: Agricultural Crop Issues and Policies, National Research Council (Washington, D.C.: National Academy Press, 1993).

[3]Cox, T.S., "The Contribution of Introduced Germplasm to the Development of U.S. Wheat Cultivars," Use of Plant Introductions in Cultivar Development, Part 1, CSSA Special Publication No. 17, 1991.

[4]A wild species is one that has not been subject to breeding to alter it from its state.

In breeding plant germplasm into a narrowing genetic base of highly productive crop varieties, breeders have also reduced the genetic diversity of these crops, making them more uniform. Genetic uniformity in breeding also results when breeders inadvertently eliminate certain traits (such as resistance to disease and pests) that do not contribute directly to the desired characteristic (such as high yield) for which they were searching. While the resulting genetic uniformity can offer substantial advantages in both the quantity and quality of a commercial crop, it can also make crops more vulnerable to pests, diseases, and environmental hazards.[5] A narrow genetic base presents the potential danger of substantial crop loss if a crop's genetically uniform characteristics are suddenly and adversely affected by disease, insects, or poor weather. The risk of loss through the genetic vulnerability of uniform, common-origin planted crops is a serious concern.

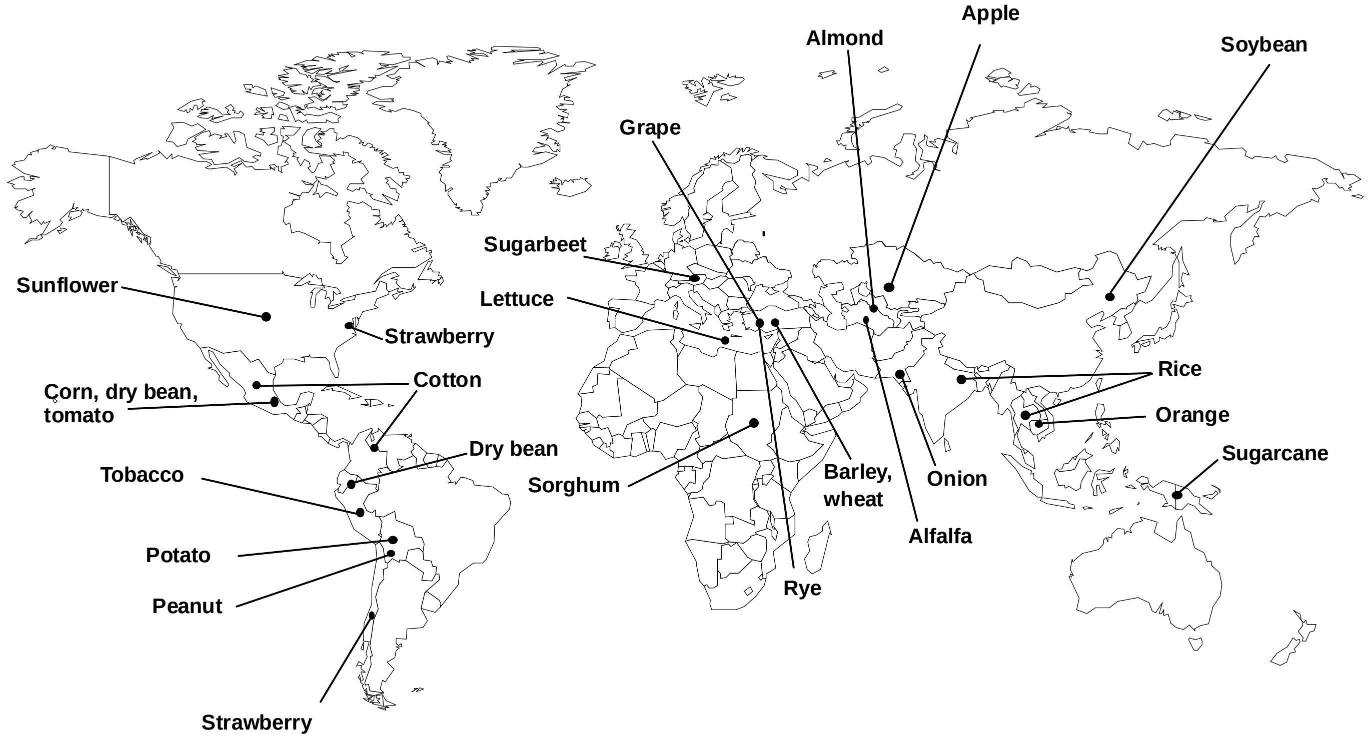
Such losses have occurred in the past. The Irish potato famine of the 1840s was a major factor in the death, impoverishment, and emigration of millions of Irish people. A single variety of the potato became Ireland's staple food after its arrival from South America in the eighteenth century. The widespread use of this single variety increased the potato crop's vulnerability to a previously unknown blight, which devastated a number of successive potato harvests. While the United States has not experienced such a widespread loss, several sizable crop failures have occurred as a result of a crop's vulnerability to a particular disease. For example, in the late 1950s and early 1960s, about 70 percent of the wheat crop in the Pacific Northwest was wiped out by a disease known as stripe rust. In 1970, a disease known as the southern corn leaf blight swept from the southeastern United States to the Great Plains, costing farmers 15 percent of their corn crop that year.

Most Germplasm for U.S. Crops Comes From Other Countries

U.S. agriculture is based on crops that originated from areas outside of the United States. For example, as shown in figure 1.1, corn originated in Mexico and Guatemala, wheat in the Near East (in such countries as Iran), and soybeans in China. Crops of economic importance that are native to the United States are limited and include sunflowers, cranberries, blueberries, strawberries, and pecans. Thus, almost all the germplasm needed to increase the genetic diversity of U.S. agriculture comes from foreign locations.

[5] Increased vulnerability can occur because genetically similar varieties or hybrids of a crop create a dependence on a single genetic source of resistance. Insects and pathogens are continually evolving, and in genetically uniform crops, the pest may need to overcome only one set of resistance genes—as opposed to numerous sets of resistance genes in a genetically diverse farm landscape.

Figure 1.1: Centers of Origin of Selected Crops



Note: The pointer locations indicate general regions where crops are believed to have first been domesticated. In some cases, the center of origin is uncertain. Other geographic regions also harbor important genetic diversity for these crops.

Source: This map was developed by GAO using data provided by NPGS' Plant Exchange Office.

While immigrants to the United States, including the first colonists from Europe, brought seeds with them, native North Americans had already introduced corn, beans, and other crops from Central and South America. Today, to obtain new germplasm for U.S. collections, plant breeders and researchers often rely on collections located in foreign countries or on plant exploration trips to the centers of origin for their crops. Between 1986 and 1996, an estimated 75 percent of the germplasm samples added to NPGS' collections were obtained from foreign countries.

Although plant exploration trips are an important source of germplasm, most of the germplasm in NPGS has been obtained from existing collections both in the United States and in foreign national and international collections. Some of the U.S. and foreign collections belong to universities and private companies. Other foreign collections include (1) an international collection based in 16 international agricultural research centers that is administered by the Consultative Group on International Agricultural Research[6] and (2) foreign national collections.

The international agricultural research centers, located primarily in developing countries, specialize in research intended to enhance the nutrition and well-being of poor people through sustainable improvements in the productivity of agriculture, forestry, and fisheries. These centers, according to the International Plant Genetic Resources Institute,[7] have together assembled the world's largest international collection of plant genetic resources for food and agriculture. They account for a significant proportion, possibly over 30 percent, of the world's unique germplasm samples maintained in collections away from their native environment. The international research centers are funded by voluntary contributions, and their plant germplasm has historically been freely available to any user. Moreover, users have not applied intellectual property protection to the material. The United States works cooperatively with these centers to support international activities to preserve germplasm. For example, U.S. germplasm facilities maintain duplicate collections for some of the international centers to provide for secure backup. In addition, U.S. scientists help various centers screen germplasm for resistance to pests and pathogens and serve in scientific liaison roles between the centers and the U.S. Agency for International Development.

Finally, many countries, including most European nations, maintain germplasm collections. These national collections vary considerably in terms of the quality of preservation, organizational structure, the number of crops preserved, and the access provided to requesters. One of the largest collections of plant germplasm in the world is maintained at Russia's Vavilov Institute of Plant Industry, named for the Russian scientist who was a pioneer in the study of plants.

[6]The purpose of the consultative group is to promote sustainable agriculture for food security in developing countries. The consultative group is jointly sponsored by the World Bank, the Food and Agriculture Organization of the United Nations, the United Nations Development Program, and the United Nations Environment Program. Fifty-three members, including the United States, provide funds that support the consultative group.

[7]The International Plant Genetic Resources Institute is an autonomous, international scientific organization sponsored by the consultative group.

Profile of USDA's National Plant Germplasm System

The National Plant Germplasm System is primarily a federally and state-supported effort aimed at maintaining supplies of germplasm with diverse genetic traits for use in breeding and scientific research. While NPGS has been evolving since USDA established its plant-collecting program in 1898, the main components of NPGS were not established until the passage of the Agricultural Marketing Act of 1946. The act also provided a legal basis for state and federal cooperation in managing crop genetic resources. The current organizational structure of NPGS—a geographically dispersed network of germplasm collections administered primarily by USDA's Agricultural Research Service (ARS)—emerged in the early 1970s. Although ARS provides the lion's share of support for NPGS, the system is also supported by the agricultural experiment stations at the state level.[8] In addition, private industry provides some support for selected projects and develops and transfers germplasm in the form of plant hybrids and varieties to farmers and other consumers.

NPGS' major activities are (1) acquiring germplasm, (2) developing and documenting information on the germplasm in its collections, and (3) preserving the germplasm. (See table 1.1.) NPGS also distributes samples, free of charge, on request to plant breeders and other scientists. NPGS maintains about 440,000 germplasm samples for over 85 crops. In 1996, NPGS distributed about 106,000 germplasm samples to requesters in the United States and in 94 countries; it received about 7,800 germplasm samples, about 5,000 of which originated in foreign countries.

Table 1.1: NPGS' Major Activities

Activity	Description
Acquisition	Collecting plant germplasm from natural habitats and through exchange with other scientists or collections.
Development and documentation of information	Development—characterizing some of the germplasm's genetic traits, such as height and color. Documentation—entering these and other data in NPGS' database, called the Germplasm Resources Information Network.
Preservation	Storing and maintaining germplasm to ensure a diverse supply of germplasm. In addition, NPGS distributes germplasm to breeders and other researchers.

NPGS is responsible for developing characterization information—data on traits such as plant structure and color that are little influenced by the environment. However, other information critical to the use of NPGS germplasm and documented in the Germplasm Resources Information

[8]Agricultural experiment stations are supported primarily by the states but also receive support from USDA's Cooperative State Research, Education, and Extension Service.

Network (GRIN) is generally developed outside of NPGS. (GRIN, a database of NPGS' holdings, is available to scientists and researchers worldwide.) For example, most evaluation data, which document traits typically affected by environmental conditions (e.g., plant yield and disease resistance), are developed outside of NPGS.[9] These data are particularly important in providing plant breeders with the information they need to select the specific germplasm samples they seek from the sometimes thousands of possible choices offered by NPGS. Passport data, often provided by the person or organization that collected or supplied the germplasm, document the geographic origin and ecological conditions of its site of origin.

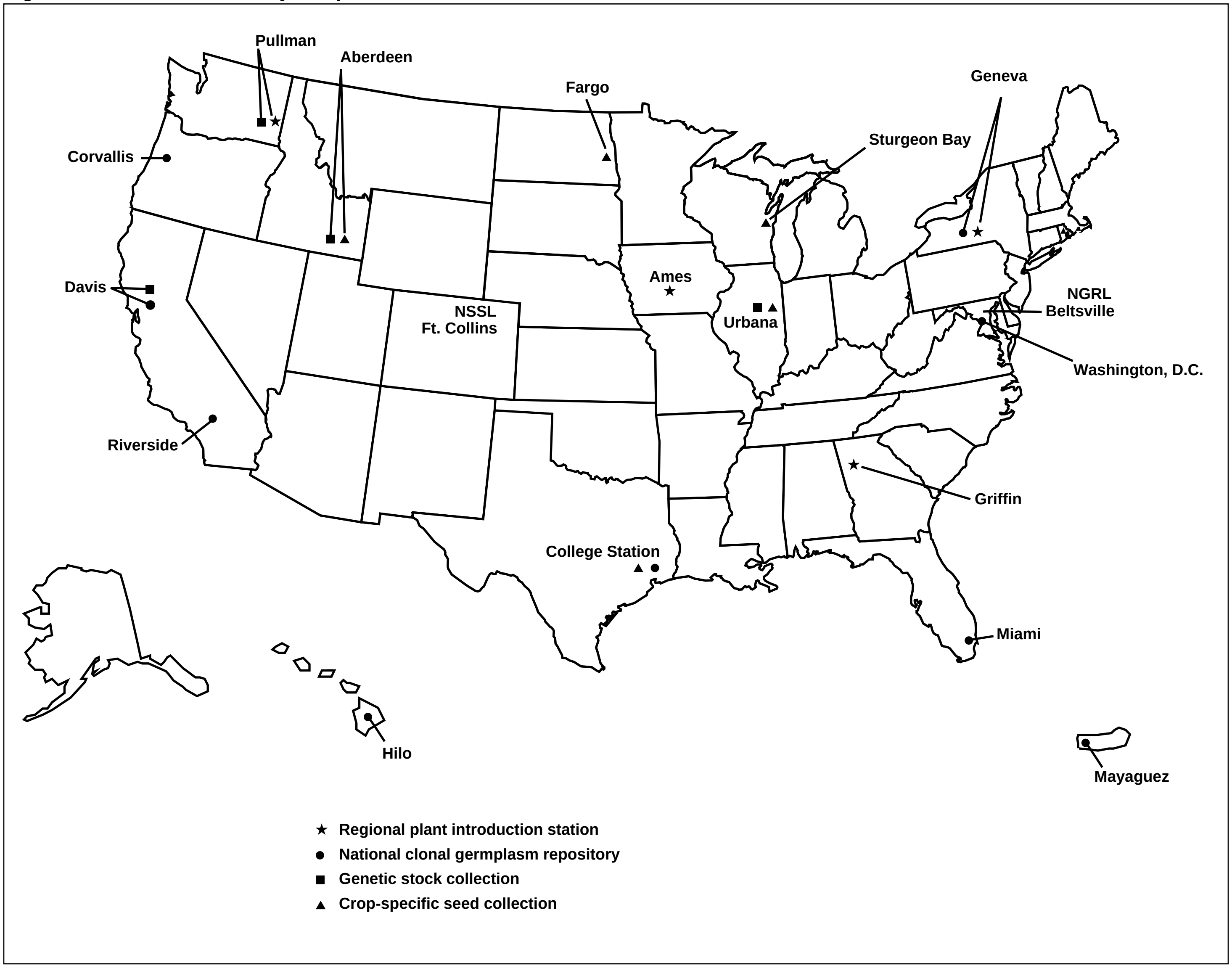
Other germplasm collections in the United States—beyond NPGS'—are maintained by private companies, institutions such as universities and state agricultural experiment stations, and nonprofit organizations such as the Seed Savers Exchange. Some of these collections, as well as some foreign collections, are not freely available to users of germplasm. Although NPGS could not provide information on the number, size, and condition of all of these collections, they represent a substantial germplasm pool.

NPGS Maintains Germplasm Collections at Sites Throughout the United States

NPGS maintains collections at 22 sites throughout the United States and in Puerto Rico. In addition, staff at 10 other sites work cooperatively with NPGS but do not receive NPGS funding. NPGS also maintains the National Seed Storage Laboratory (NSSL) and the National Germplasm Resources Laboratory (NGRL). Figure 1.2 shows the locations of these sites and laboratories.

[9]Up until 1992, NPGS received funding for germplasm evaluations. Since then, funding for these evaluations has been transferred from NPGS to other ARS research programs.

Figure 1.2: NPGS Sites of Major Importance



Source: NPGS.

While most NPGS collections are maintained at sites that house germplasm for numerous crops, NPGS also has five sites that specialize in crop-specific collections, such as potatoes or soybeans. In addition, NPGS has nine sites that are national clonal germplasm repositories and four that maintain genetic stock collections.[10] The four regional plant introduction stations[11] are responsible for maintaining many of the major seed-reproducing species held by NPGS. In total, as of June 1997, they accounted for almost half of the germplasm samples maintained in NPGS collections.

NPGS sites generally contain either "backup" or "active" collections, depending on the storage objectives.[12] Backup collections maintain germplasm for long-term conservation, and active collections maintain germplasm for short- to medium-term conservation and distribution. Germplasm is maintained either as seeds or as living plants. The latter category is generally referred to as "clonal" germplasm and includes fruit trees, sugarcane, and strawberries. Clonal germplasm is likely to lose some of its distinct genetic characteristics when reproduced from seed; therefore, it is reproduced asexually from its own plant parts. Clonal germplasm can be costly to preserve. Some fruit trees, for example, may require isolation to prevent loss from pests as well as screened protection and other measures to ensure the normal development of plants or to keep the fruit free of pests.

At each site, crop curators and other staff are responsible for maintaining the germplasm collections. Curators regenerate (or replenish) germplasm samples by growing additional plants from seed or other plant parts to ensure that an adequate number of samples are available for (1) distribution to plant breeders, research scientists, and institutions and (2) storage in long-term collections. In the process of regeneration, curators must ensure that each plant generation is as genetically similar to its predecessor as possible. During regeneration, curators also document certain plant characteristics (such as plant height and color) if this information is not already available. Curators and other staff are responsible for entering information about each germplasm sample into GRIN.

The National Seed Storage Laboratory (NSSL) at Fort Collins, Colorado, maintains the long-term backup collection of seeds for NPGS and some non-NPGS collections located in the United States and foreign countries and conducts research on preserving plant germplasm. NSSL's storage facilities

[10]Clonal repositories hold germplasm (e.g., fruit trees) that are maintained as living plants or plant parts. Genetic stock collections contain germplasm with one or more special genetic traits that make them of interest to researchers.

[11]The four regional plant introduction stations—located at Ames, Iowa; Pullman, Washington; Geneva, New York; and Griffin, Georgia—are jointly operated by ARS and the state agricultural experiment stations of the region.

[12]According to ARS, genetic stock collections are classified separately because specialized care and trained personnel are needed to maintain them.

were modernized and expanded fourfold in 1992, with high-security vaults to protect the germplasm against natural disasters. The collection duplicates (or backs up) many of the germplasm samples in NPGS' active collections in the event that the germplasm kept in active collections is lost. Germplasm can be lost for a variety of reasons, including natural disasters or degeneration through inadequate storage. Seeds preserved at NSSL are kept in colder, more secure conditions (i.e., sealed, moisture-proof containers in vaults at –18 degrees Celsius or containers over liquid nitrogen at –160 degrees Celsius) that preserve them longer than seeds preserved at many active sites.[13] With few exceptions, such as apple buds that can be preserved in liquid nitrogen, NSSL does not back up clonal germplasm. Clonal collections may be backed up—in greenhouses, as tissue culture, or through cryopreservation—[14] at the same sites as their active collections.

The National Germplasm Resources Laboratory, located in Beltsville, Maryland, contains several units that support NPGS. The Plant Exchange Office—with extensive input from the CGCs and NPGS' crop curators—is responsible for setting priorities for the germplasm needs of NPGS' collections. Furthermore, the Office coordinates plant exploration trips, facilitates germplasm exchanges with other collections, and documents the entry of germplasm into NPGS, including its passport data. In addition, the Germplasm Resources Information Network/Database Management Unit manages GRIN, NPGS' database, which provides information for users and managers, such as passport information on NPGS samples.

ARS' Plant Germplasm Quarantine Office works with USDA's Animal and Plant Health Inspection Service (APHIS) in administering the National Plant Germplasm Quarantine Center in Beltsville, Maryland.[15] These sites test specific types of imported germplasm for pests and pathogens before the germplasm is introduced into the United States. All plant germplasm coming into the United States must comply with federal quarantine regulations intended to prevent the introduction of pests and pathogens that are not widespread in the United States. APHIS writes, interprets, and enforces quarantine regulations, while ARS is generally responsible for providing research support, including the development of tests for pests

[13]In contrast, seeds in many active collections are generally stored at 5 degrees Celsius, although active collection sites are increasing the use of storage at –18 degree Celsius to reduce losses.

[14]Tissue culture is a technique for cultivating cells, tissues, or plant parts in a sterile, synthetic medium. Cryopreservation involves maintaining tissues or seeds in long-term storage at ultralow temperatures, typically between –150 degrees and –196 degrees Celsius.

[15]In addition, ARS administers a quarantine facility in St. Croix, U.S. Virgin Islands, that tests corn, sorghum, and millet.

and pathogens. In addition, ARS, through a 1986 Memorandum of Understanding with APHIS, maintains and tests germplasm that falls into the "prohibited" quarantine category.[16]

Support for NPGS Comes From Several Sources

NPGS' activities are supported at the federal level primarily by ARS, with additional support provided by states' land grant universities through their agricultural experiment stations. Many of NPGS' collections have been jointly developed and maintained by federal and state scientists at states' agricultural experiment stations, and most NPGS sites are located on experiment station properties. State universities provide in-kind support in the form of services, personnel, and facilities. In addition, private industry provides limited support, such as regenerating germplasm at company sites or funding special projects.

In fiscal year 1996, NPGS funding was $23.3 million. Of this amount, $19.5 million was provided by ARS; $1.4 million by USDA's Cooperative State Research, Education, and Extension Service; $1.3 million by APHIS; $0.8 million (in-kind support) from the states' agricultural experiment stations; and $0.3 million from other nonfederal sources. Included in the ARS funding was $3.9 million for plant collection activities—germplasm acquisition, quarantine, and classification—and $15.6 million for such activities as preservation, documentation, and distribution. From fiscal years 1992 through 1996, ARS' funding for NPGS has been essentially level; however, if calculated in constant dollars, funding declined by 14 percent during this period. During this period, NPGS' germplasm collections increased by 10 percent.

Management of NPGS Is Highly Decentralized

While ARS has the primary responsibility for managing NPGS, no single individual or entity has overall authority for managing the entire system. Within ARS, numerous officials and committees have different levels of authority and responsibility for components of the system.

ARS' National Program Leader for Plant Genetic Resources has a broad range of leadership responsibilities for the system, including developing budget proposals, planning resource allocations among the NPGS sites, and addressing international issues affecting germplasm.[17] The program leader

[16]The prohibited category is the most stringent quarantine category, requiring that germplasm be sent to a quarantine facility for testing or observation before it is introduced into the United States.

[17]The position of national program leader for plant genetic resources has been vacant for the past 5 years. There have been five acting program leaders during this period.

also participates in and is advised by various groups that make recommendations concerning NPGS' operations and policies. The program leader, however, has limited authority for the budgets, projects, or management of each NPGS site. Responsibility for these activities rests with (1) ARS' area directors, who have direct oversight responsibility and authority for the NPGS sites located within their areas of jurisdiction, (2) NPGS' site leaders, and (3) ARS' national program staff. In particular, the area directors coordinate some site program reviews, conduct performance ratings for key administrative staff, hire personnel, and manage discretionary funding for NPGS sites located in their jurisdiction.

Because of the broad array of crops represented in NPGS' collections—each requiring specific scientific and technical expertise—NPGS relies on 40 Crop Germplasm Committees (CGC) to provide expert advice on technical matters relating to germplasm activities. Among other things, the CGCs are expected to provide recommendations on the management of the germplasm collections for their crops, including setting priorities for acquisition and evaluation research. CGC members—representing ARS, universities, and the private sector—include plant breeders, NPGS curators, pathologists, and other scientists who are experts on specific crops. A crop committee can represent one crop group or several. For example, the soybean CGC provides advice on soybeans, while the leafy vegetable CGC is responsible for lettuce, spinach, chicory, and celery. (See app. III for a listing of the CGCs and the crops for which they are responsible.) These committees generally meet about once a year and issue reports on the status of their respective collections. However, they receive no funding for their work or related expenses.

Past GAO and National Research Council Reports Have Cited Many NPGS Shortcomings

GAO and National Research Council reports, dating as far back as 1981, have cited management and organizational shortcomings and needs that have hindered NPGS' overall effectiveness. In 1981, for example, GAO concluded that insufficient management attention by USDA to germplasm collection, storage, and maintenance had endangered the preservation of germplasm in the United States.[18] Another GAO report, issued earlier that year, recommended that USDA centralize control over the Department's genetic resources and develop a comprehensive plan for their use.[19] In

[18] Better Collection and Maintenance Procedures Needed to Help Protect Agriculture's Germplasm Resources (CED-82-7, Dec. 4, 1981).

[19] The Department of Agriculture Can Minimize the Risk of Potential Failures (CED-81-75, Apr. 10, 1981).

1990, GAO reported that ARS had difficulty in setting priorities and allocating funding among the various plant germplasm management activities.[20]

In a comprehensive evaluation of NPGS issued in 1991,[21] the National Research Council concluded that NPGS had no discernible structure and organization for managing and setting priorities for its activities, formulating national policies, or developing budgets to act on emerging priorities. The Council made many recommendations, including that USDA strengthen NPGS by centralizing its management and budgeting functions and by establishing clear goals and policies for NPGS' leadership to use in developing long-range plans. Other recommendations included expanding the capacity of NSSL and providing financial support to the CGCs.[22]

During the 1990s, USDA has made several changes to address some of the operational shortcomings discussed above. In particular, it has expanded NSSL's long-term, secure storage facility fourfold. Furthermore, NPGS' sites with active collections are making greater use of –18 degree Celsius storage to improve germplasm preservation. In addition, NPGS' GRIN database has been substantially improved by the addition of such features as a new search function and access to users through the Internet.

Objectives, Scope, and Methodology

We surveyed the members of the 40 CGCs for their views on the sufficiency of NPGS' principal activities—acquiring germplasm to ensure the diversity of the collections in order to reduce crop vulnerability, developing and documenting information on germplasm, and preserving germplasm. Specifically, we surveyed the 680 members of the CGCs—including 38 additional experts identified by USDA. The median CGC response rate was 86 percent, and all NPGS curators participated in the survey. We conducted this survey from November 1996 through March 1997.

In addition, we obtained information about NPGS' major activities—acquisition, development and documentation of information, and preservation—from interviews with the following: two acting National Program Leaders for Plant Genetic Resources; several NGRL officials responsible for plant exploration, quarantine, and GRIN; the Director, National Plant Germplasm Quarantine Center, APHIS; the Director and research leaders, NSSL; the site leaders of the four regional plant

[20] Plant Germplasm: Improving Data for Management Decisions (PEMD-91-5A, Oct. 10, 1990).

[21] Managing Global Genetic Resources: The U.S. National Plant Germplasm System, National Research Council (Washington, D.C.: National Academy Press, 1991).

[22] NSSL was expanded in 1992. The CGCs were formerly called the Crop Advisory Committees.

introduction stations and the Davis, California clonal repository; a number of curators and breeders at various NPGS sites; and ARS budget staff. We visited NGRL and APHIS officials in Beltsville, Maryland; two of the four regional plant introduction stations (Ames, Iowa, and Griffin, Georgia); the National Soybean Collection, Urbana, Illinois; and NSSL in Fort Collins, Colorado. We also interviewed officials from USDA's Economic Research Service; Pioneer Hi-Bred International, Inc., a large seed producer; the Department of State; and the Agency for International Development.

In addition, we reviewed (1) NPGS program documents, including planning and budget documents; (2) acquisition and preservation data (based on GRIN data) provided to us by NGRL officials, as well as preservation data provided by officials from the four plant introduction stations; (3) CGC reports; (4) site and program reviews; and (5) documents from the Food and Agriculture Organization of the United Nations and from international sources related to germplasm access. We did not verify the accuracy and reliability of the data provided by NPGS.

We conducted our review from July 1996 through September 1997 in accordance with generally accepted government auditing standards. We provided USDA with a draft of our report for review and comment. These comments and our response to them are in appendix IV.

CGCs Underscored Importance of Acquiring Germplasm to Increase Genetic Diversity, but Some Obstacles Hinder Acquisition

Most CGCs reported that the overall diversity in freely available germplasm collections[1]—including NPGS'—is sufficient for reducing their crops' vulnerability. Nonetheless, they ranked the acquisition of additional germplasm as a top priority for NPGS, thereby underscoring the importance they place on having maximum genetic diversity in NPGS' collections. A number of issues may be contributing to the CGCs' emphasis on acquiring germplasm for the NPGS collection. For example, most CGCs said that at least one of the four types of germplasm that generally constitute their collections is inadequate; each type contains genetic material that plays an important role in a collection's overall diversity.

Most CGCs considered acquiring more germplasm to be a top priority; however, problems with some countries have hindered access to potential sources of new germplasm in those areas. In addition, certain provisions in the Convention on Biological Diversity, which entered into force in 1993, may place constraints on the use of and access to some foreign germplasm in the future.

Even when NPGS acquires new germplasm, its release to breeders and research scientists has sometimes been delayed as a result of problems in USDA's management of the quarantine process. According to many CGCs whose germplasm generally undergoes the most intensive quarantine testing, the process has resulted in the delayed release and, to a lesser extent, the loss of some germplasm.

Most CGCs Reported That Germplasm Collections Are Sufficiently Diverse, but They Still Want to Increase Germplasm Acquisition

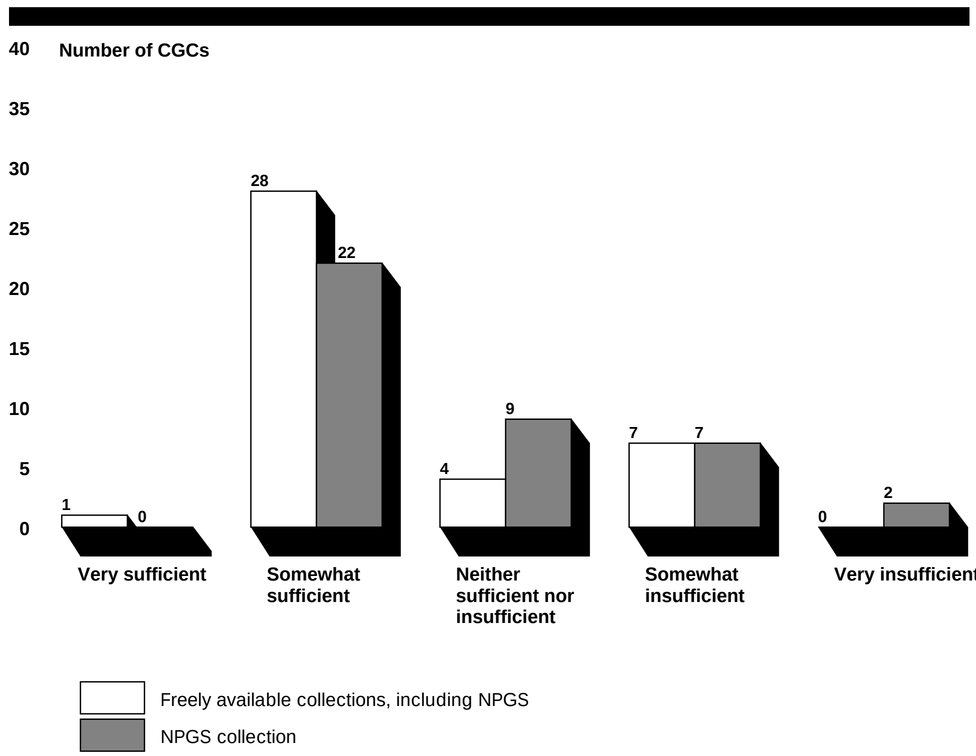
When all freely available collections were taken into account, almost three-quarters of the CGCs reported that these collections are sufficiently diverse for reducing the vulnerability of their crops. For the NPGS collections alone, just over half the CGCs reported that the genetic diversity of their NPGS collections is sufficient to reduce crop vulnerability. Nonetheless, the CGCs overall viewed the acquisition of additional germplasm as a top NPGS priority—out of 14 germplasm-related activities—in the event of additional funding. Several concerns highlighted by the CGCs in our survey may contribute to the importance they place on increased acquisition. These concerns include the lack of diversity within specific parts of their collections and the potential loss of germplasm that is endangered in nature or in at-risk collections (e.g., collections of scientists who are retiring).

[1]Freely available (i.e., without restrictions) collections include NPGS' and international collections as well as some university and private collections and many foreign national collections. It is always possible that a collection that is currently freely available may, in the future, become restricted or unavailable.

Most CGCs Believed That Germplasm Collections Have Sufficient Diversity

When all freely available collections (including NPGS') were considered, 29 of the 40 CGCs reported that the genetic diversity in the collections for their crops is sufficient for reducing crop vulnerability. Major crops—such as corn, wheat, and soybeans—are in this category. The sufficiency of the collections declined somewhat when only NPGS collections were considered: Twenty-two, or just over half of the CGCs reported that the NPGS collections for their crops have sufficient genetic diversity overall to reduce crop vulnerability. (See fig. 2.1.)

Figure 2.1: CGCs' Perceptions of the Diversity of All Freely Available Collections and of the Diversity of the NPGS Collections for Their Crops

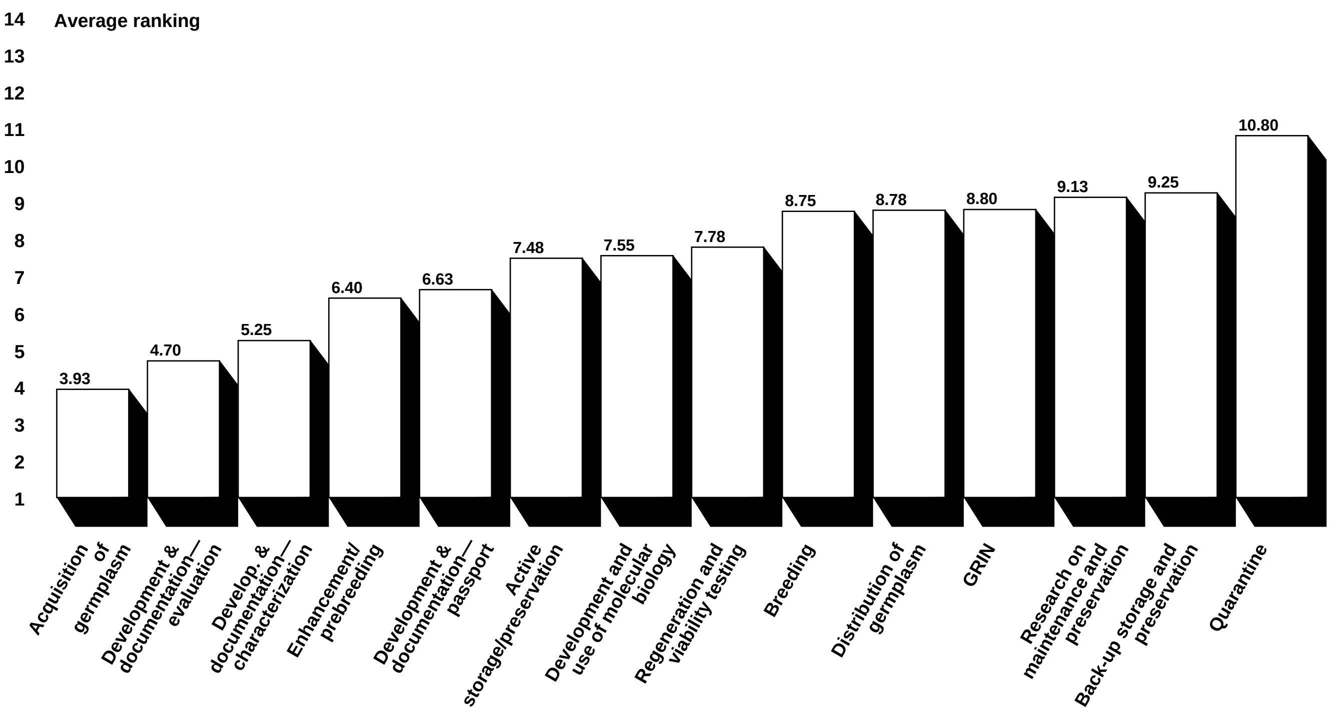


Nine CGCs said that the genetic diversity of the NPGS collection for their crops is insufficient for reducing crop vulnerability: grapes, cool season food legumes, sweet potatoes, cucurbits (e.g., squash and melons), tropical fruit and nut, walnuts, herbaceous ornamentals, prunus (e.g., peach and cherry trees), and woody landscape. In addition, nine CGCs said that their collections have neither sufficient nor insufficient diversity.

CGCs Believed That Germplasm Acquisition Should Be a Top Priority for NPGS

While over half the CGCs believed that the genetic diversity of their NPGS germplasm collections for their crops is sufficient, they all reported that it is moderately to extremely important to increase the diversity of their NPGS collections.[2] The importance the CGCs placed on increasing diversity is underscored by the high priority given to germplasm acquisition in the event of additional funding—of 14 germplasm-related activities, the CGCs, on average, gave acquisition the highest ranking. (Fig. 2.2 shows the average ranking that CGCs gave to each activity, with 1 being the highest possible ranking.)

Figure 2.2: CGCs' Ranking of the Priority to Be Given to 14 Germplasm-Related Activities in the Event of Additional Funding



Note: If all 40 CGCs ranked one activity as their first priority, then its average ranking would be 1. Enhancement and breeding are ancillary NPGS activities and are primarily funded by other ARS programs and by universities and the private sector.

[2]Of the 40 CGCs, 14 reported that it is moderately important, 25 reported that it is very important, and 1 reported that it is extremely important to increase the genetic diversity of their collections.

All 40 CGCs stated that they knew of germplasm samples that would increase the genetic diversity of the NPGS collections and that should be added to them. For example, the Wheat CGC's 1996 report to NPGS cited three critical collection needs for the NPGS wheat collection and specified where much of this germplasm could be obtained, including landraces (seeds passed down by farmers from one generation to another to produce desired plant characteristics) from Guatemala, where they have not been collected before, and wild wheat relatives from Albania, Greece, and the former Yugoslavia. Similarly, the Sweet Potato CGC wanted to enhance the limited genetic diversity of the NPGS sweet potato collection by obtaining a representative sample of germplasm from the International Potato Center in Peru. This collection contains about 6,500 germplasm samples of sweet potato, compared with about 1,170 in the NPGS collection.

Several Problems Associated With the Collections May Contribute to Priority Given to Germplasm Acquisition

Although most CGCs reported that their NPGS collections overall are sufficiently diverse at this time, they cited several concerns with the collections that may account for the importance they place on increased acquisition. First, most CGCs reported that at least one of the following types of germplasm in their collections is insufficiently diverse for reducing crop vulnerability: wild and weedy relatives of cultivated crops, landraces, and genetic stocks. Only obsolete and current cultivars, the fourth type of germplasm samples in a collection, are considered to be sufficient by most CGCs. Specifically:

- Wild and weedy relatives of crops were reported to be insufficient by almost half the CGCs, including those for major crops such as corn and soybeans. Wild relatives have often been used to improve crops, such as tomatoes, and sometimes to develop new ones.
- Landraces—many of which are grown from selected quality seed passed down by farmers from one generation to another—were reported to be insufficient by 12 of the 40 CGCs. Landraces are rich sources of genes for traits such as resistance to pests and pathogens.
- Genetic stocks are insufficiently diverse, according to over half the CGCs, including those for major crops such as alfalfa, peanuts, and grapes. While genetic stock material is essential to genetic research, according to NPGS officials, it has generally played a minor role in commercial breeding programs. However, it is expected to become increasingly important in breeding programs that use molecular genetic tools to manipulate and

transfer genes to create new products, according to the National Research Council.[3]

- Obsolete and current cultivars are sufficient for reducing the vulnerability of their crops, according to most CGCs. Only five CGCs cited insufficiencies in this area.

Furthermore, 39 CGCs said that NPGS should place increased emphasis on acquiring germplasm endangered in nature or acquiring germplasm from collections at risk, such as the Vavilov collection in Russia or the collections of scientists who are retiring. If such collections are not obtained and preserved, their germplasm may be lost. Finally, 37 CGCs reported that certain plants are becoming extinct or hard to find.[4]

NPGS' acquisition policy is to rely heavily on the 40 CGCs and the NPGS curators to assess the adequacy of their respective germplasm collections and recommend areas where additional acquisition may be needed. However, NPGS has not developed a comprehensive, long-term plan to establish critical acquisition needs for its germplasm collections and priorities for collection trips to fill those needs. Currently, NPGS' collection trips are based primarily on proposals that are submitted to NPGS' Plant Exchange Office by federal and university scientists and endorsed by the appropriate CGCs. In addition, staff from the Plant Exchange Office occasionally make or participate in collection trips. However, some exploration trips are funded by other USDA or non-USDA federal agencies.[5]

According to NPGS officials in the Plant Exchange Office, some germplasm collections are more frequently targeted for collection trips than others because (1) the gaps in some collections are better known and (2) some collections have more assertive champions—e.g., a germplasm curator, CGC, or other interested scientist who aggressively seeks out collection opportunities. This approach may overlook the needs of some crops. For example, according to the head of the Plant Exchange Office, 16 of the CGCs' reports state acquisition needs only in a general fashion and therefore are of limited value for planning or setting acquisition priorities.

[3]Managing Global Genetic Resources: Agricultural Crop Issues and Policies, Board on Agriculture, National Research Council (Washington, D.C.: National Academy Press, 1993).

[4]As discussed in ch. 1, there are also concerns about the vulnerability of crops to pests and pathogens. All 40 CGCs reported that such risk is a serious problem for their crops: Six said genetic vulnerability is a very serious problem, 30 said it is moderately serious, and 4 said it is somewhat serious. The six CGCs reporting very serious problems represented oats, cool season food legumes, tropical fruit and nut, grapes, walnuts, and prunus.

[5]The Plant Exchange Office often works with other agencies within USDA and other agencies, such as the U.S. Agency for International Development, to obtain funding.

The exchange officer acknowledged the need to develop a long-term plan that would reflect collection priorities for each crop. He noted that such a plan would use existing funds more efficiently and help ensure that the needs of all crops are being addressed. NPGS has been working to develop such a plan for several years, but progress has been slow because the office has lacked the resources to adequately staff the project and provide needed scientific expertise. The initial plan, which is intended to be flexible to accommodate changing needs and conditions, is expected to be completed by Spring 1998.

Concerns about NPGS' acquisition planning process are long-standing. For example, over 15 years ago, GAO recommended that a long-range plan be developed to address gaps in germplasm collections and objectives for collecting or otherwise acquiring needed germplasm.[6] In 1991, the National Research Council recommended, among other things, that NPGS develop a comprehensive plan for plant exploration. The Council noted that in the past, the lack of an exploration plan resulted in some crops receiving attention, while others went unserved.[7]

CGCs Report Problems in Acquiring Foreign Germplasm

Although CGCs want to acquire more germplasm, most reported that difficulties between the United States and some foreign countries have hindered NPGS' efforts to obtain the germplasm needed to increase the diversity of its collections.[8] For example, the Soybean CGC report indicated that relations between the United States and North Korea have hindered the CGC from obtaining germplasm from North Korea. The report stated that the few soybean germplasm samples from North Korea in NPGS' collection were either obtained more than 60 years ago or have been received since then through third parties. Several other CGC reports—including those for sugarbeets, peas, and wheat—cited difficulties in obtaining germplasm from the Middle East. The Wheat CGC, for example, noted that Iran, a country with which the United States does not have diplomatic relations, holds potentially valuable wheat germplasm.

[6] The Department of Agriculture Can Minimize the Risk of Potential Crop Failures (CED-81-75, Apr. 10, 1981).

[7] The U.S. National Plant Germplasm System: Managing Global Genetic Resources, National Research Council (Washington, D.C.: National Academy Press, 1991).

[8] Of the 40 CGCs, 13 reported that long-standing political difficulties had hindered the acquisition of germplasm from foreign countries to some extent, 22 to a moderate extent, and 4 to a great extent. One CGC said that such difficulties created little or no hindrance in NPGS' ability to increase diversity for its crop collection.

In addition, issues relating to the ownership and use of foreign germplasm have become more problematic as a result of the entry into force of the Convention on Biological Diversity in 1993.[9] Prior to the Convention, germplasm from most countries, other than those where access was restricted, has been generally available to requesters. However, the Convention recognizes the sovereign rights of nations over their natural resources and their rights to exchange these resources under terms mutually agreeable to the nation and the germplasm recipient. Officials from NPGS, the State Department, the Agency for International Development, and the World Bank observed that access to plant germplasm could be reduced as a result of these provisions but that the full impact of the Convention may be unknown for a number of years.

However, one likely result of the Convention will be the increased use of material transfer agreements—contracts that require germplasm users to agree to certain conditions in exchange for the use of the germplasm. These agreements may require, for example, that the requester not seek intellectual property rights or claim ownership over the germplasm. USDA officials will sign material transfer agreements only if their terms are consistent with NPGS' policy to provide users with free and open access to germplasm.

USDA's Management of Quarantine Program Has Hampered Acquisition of Some Germplasm

A number of problems related primarily to USDA's overall management of the germplasm quarantine program have hampered the program's effectiveness and resulted in delays in the release of some germplasm. While most CGCs reported that U.S. quarantine regulations and processes have been effective in reducing the introduction of pests and pathogens into the United States, 13 CGCs, most of whose germplasm often undergoes more intensive scrutiny in quarantine, reported problems with the timeliness of the quarantine process, and 5 reported problems with the release of viable germplasm. While the CGC for prunus (e.g., cherry and peach trees) reported that USDA's regulations and processing have been very ineffective in both of the above areas, CGCs for crops such as apples, pears, potatoes, and corn also reported problems.

[9]The Convention on Biological Diversity is a legally binding framework—for countries that have consented to it—for conserving and utilizing global diversity. The U. S. Congress has not yet consented to it.

Poor Crop Production Practices, Inadequate Facilities, and Outmoded Testing Procedures Have Created Problems for Quarantined Germplasm

All plant germplasm coming into the United States must comply with federal quarantine regulations intended to prevent the introduction of pests and pathogens not widespread in the United States. These regulations range from a category requiring only visual inspection at the port of entry for germplasm such as the seeds of most vegetables and flowers, to a category—known as "prohibited"—requiring that the germplasm be sent to a quarantine facility for testing or observation before release.[10] Although less than 3 percent of the world's plant species are in this latter category, it includes a wide range of crops: all or most clonally propagated prunus, apples, pears, potatoes, sugarcane, strawberries, sweet potatoes, grapes, certain woody landscape plants, and grasses as well as the seeds of wheat, corn, and rice from some regions where there are serious diseases not already in the United States.

Thirteen CGCs—most of whose germplasm is often in the prohibited category—reported that USDA's management of the quarantine process hinders the timely acquisition of viable germplasm. In addition, ARS officials told us that some germplasm has died while in quarantine because it was poorly maintained.[11] The specific types of problems identified by the CGCs, ARS and APHIS officials, and ARS reviews included (1) poor production practices during quarantine, (2) inadequate facilities or sites, and (3) the types of testing procedures that are currently in use.

Poor Production Practices Have Resulted in Dead Germplasm and Delays in Release

Eleven CGCs, representing such germplasm collections as prunus, apples, pears, potatoes, and sweet potatoes, reported that poor crop production practices—such as inadequate watering, soil preparation, and weeding—during quarantine hinder the timely acquisition of viable germplasm. Furthermore, an internal review of tree-growing practices at the Maryland quarantine facility, conducted in 1996 by a horticultural scientist at the request of ARS, noted the death of several thousand fruit trees planted between 1993 and 1995.[12] The review cited improper horticultural practices as a major cause of many of the deaths and recommended improved practices.

[10] APHIS gives certain qualified importers of germplasm for some crops a permit that enables them to test and observe the germplasm in their own facilities to ensure it meets USDA regulations.

[11] According to ARS officials, some germplasm dies in quarantine because it is in poor condition when it arrives at the quarantine facility.

[12] According to the Research Leader of the National Germplasm Resources Laboratory, the trees that died were primarily trees to be used for testing purposes and generally did not include imported plant material.

When trees in quarantine are not properly maintained, they may die and their germplasm will need to be imported again. For example, an ARS scientist at the quarantine office estimated that about 20 percent of all prunus germplasm samples brought into the country in the past 10 years had died because they did not receive proper horticultural care.

In addition, poor production practices have kept trees from maturing sufficiently to permit testing, thereby delaying the release of germplasm. Such delays have occurred with the germplasm of prunus, apple, pear, and quince trees. For example, since 1991, the release of hundreds of germplasm samples for apple, pear, quince, and prunus trees has been delayed as a result of inadequate horticultural practices, according to the ARS scientists at the quarantine office who test and monitor these trees. Delays for most of the clonal apple, pear, and quince germplasm have been about 8 to 10 years.[13] Furthermore, the average time for the unconditional release of prunus germplasm at the Maryland quarantine facility has been about 10 years; however, generally no more than 4 years should be required, according to APHIS officials. ARS officials expect that it will not unconditionally release apple, pear, quince, or prunus clonal material until the year 2000 or later because of horticultural practices that have resulted in the lack of mature trees needed for testing.

Inadequate Facilities Have Hindered Health of Quarantined Plants

Thirteen CGCs—including those for prunus, pears, corn, and rice—reported that conditions at the quarantine facilities used to grow their plants hinder the timely release of viable germplasm. Problems with quarantine facilities were also reported in ARS reviews in 1994 and 1996.[14] The 1996 review stated that conditions at the quarantine facilities in Maryland were not conducive to promoting plant health. For example, it noted that the Maryland site's soil was unsuitable for growing trees and recommended the installation of space heaters in the screenhouses to keep the temperature slightly above freezing. In addition, a plant breeder on the pear CGC said that the Beltsville facility is not ideal for pears or apples because the climate of the mid-Atlantic region is conducive to the development of fire blight, a serious bacterial disease that is difficult to control once trees are infected.

[13]This refers to any release that is not conditional on any federal restrictions, e.g., requiring further observation or limiting the use of the germplasm.

[14]The 1994 review was an in-depth review of the National Germplasm Resources Laboratory, including the Plant Germplasm Quarantine Office. The 1996 review addressed tree-growing practices at the plant quarantine fields and greenhouses.

Outmoded Testing Procedures Have Contributed to Delays in Release of Germplasm

Sixteen CGCs—including the prunus, apple, pear, corn, wheat, rice, and potato CGCs—reported that required testing procedures hinder the timely acquisition (e.g., introduction and distribution) of viable germplasm for their crops.[15] While ARS is responsible for developing new tests, APHIS must approve the tests that are used as well as the release of germplasm from quarantine. Nearly all of the quarantine testing procedures currently in use date back to the early 1980s or before. These procedures involve testing for pathogens such as viruses and other infectious agents. For some crops, testing begins by closely observing the quarantined plants for symptoms of disease during plant growth and subjecting the plants to a battery of tests for latent pathogens. Some tests for trees can take considerable time because the tree must first bear fruit before tests can be completed. For example, tests on prunus trees generally require a minimum of about 3, and no more than 4, years to complete, according to APHIS officials.

More sophisticated testing methods using molecular techniques to identify pathogens are being developed, and some are already available. These tests could save considerable time in quarantine as well as the costs associated with caring for the plants during that time. Such tests could also curtail the loss of germplasm that is associated with longer quarantine periods, according to APHIS and ARS officials. ARS has developed, and APHIS has approved, molecular tests for potato viruses; these tests have cut quarantine testing from 2 years to 1, according to an ARS scientist. In addition, APHIS is currently reviewing newly developed molecular tests for detecting certain diseases in prunus that would allow the conditional release of prunus in about 18 months, on average. In addition, ARS is working on the development of molecular tests for certain sweet potato pathogens.

However, some plant breeders are concerned that the development and approval of new testing methods has been unduly slow. A 1994 review of the germplasm quarantine office, conducted by ARS and university scientists at the request of ARS, noted that virtually all popular new apple and pear trees clones of foreign origin enter the United States illegally, without pathogen testing. It stated that both ARS and APHIS needed to adopt policies that would make pathogen testing more responsive to the needs of the deciduous fruit industry and its associated germplasm collections and CGCs.

[15]The remainder of the crops were grapes, small fruits (e.g., berries), peanuts, sweet potatoes, cucurbits (e.g., melons), grass, sunflower, herbaceous ornamental plants, and woody landscape.

Many NPGS Germplasm Collections Lack Information Needed for Crop Breeding

According to most CGCs, NPGS collections for their crops lack sufficient information on germplasm traits to facilitate the germplasm's use in crop breeding. Specifically, these CGCs raised concerns about two types of information—evaluation and characterization. Evaluation information describes traits (such as yield and resistance to disease) of particular interest to plant breeders, while characterization information describes traits (such as plant structure, seed type, and color) that are little influenced by environmental conditions. Most CGCs reported that passport data—a third type of information that describes, among other things, the site of origin of the germplasm—are sufficient for breeding crops.

NPGS officials acknowledged that gaps exist in needed information, in part because the information has not been developed and in part because the information that has been developed has not always been entered into NPGS' centralized database—the Germplasm Resources Information Network (GRIN). They noted, however, that given their limited resources, the day-to-day tasks of preserving germplasm to maintain its viability take precedence over developing and documenting information.

Many CGCs Reported That Evaluation and Characterization Information Are Insufficient

Three-quarters of the CGCs reported insufficiencies with evaluation information, and almost half found characterization information insufficient for crop-breeding purposes. On the other hand, most CGCs reported that passport information is sufficient for crop-breeding purposes. Several NPGS managers told us, however, that passport information—particularly for older samples—is not adequate for NPGS' internal planning and management.

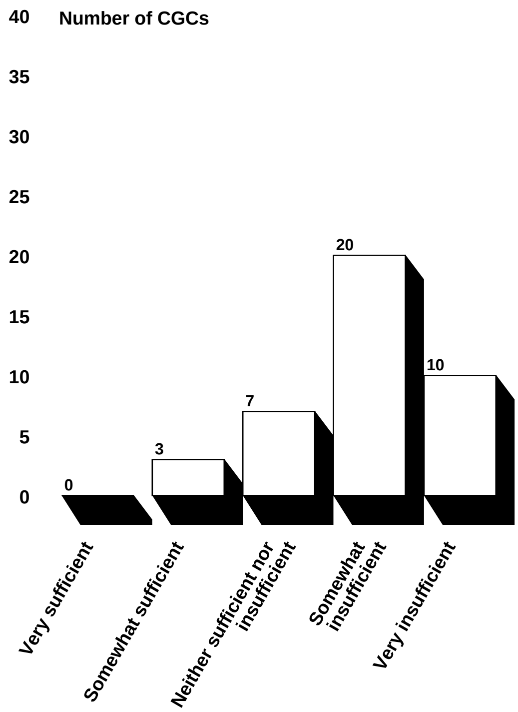
Most CGCs Believed That Evaluation Data Are Insufficient

Breeders need comprehensive evaluation information to select germplasm with the traits they are seeking from the myriad of germplasm samples. According to the National Research Council, evaluation is a prerequisite for the use of germplasm—germplasm samples that are not evaluated remain mostly curiosities.[1] In developing evaluation data, scientists test germplasm samples for various traits under a wide range of conditions. Although the preliminary evaluation of traits is generally considered an NPGS activity, most evaluations are part of the research that accompanies breeding programs and are conducted and funded primarily through other ARS programs and universities. In addition, industry conducts and funds a small amount of germplasm evaluation for NPGS.

[1]Managing Global Genetic Resources: Agricultural Crop Issues and Policies, National Research Council (Washington, D.C.: National Academy Press, 1993).

Thirty of the 40 CGCs reported that the evaluation information on their NPGS collections is somewhat or very insufficient for crop breeding, and only 3 reported that it is somewhat sufficient—the alfalfa, sugarbeets, and tropical fruit and nut CGCs. Figure 3.1 shows the sufficiency of evaluation information, as reported by the 40 CGCs.

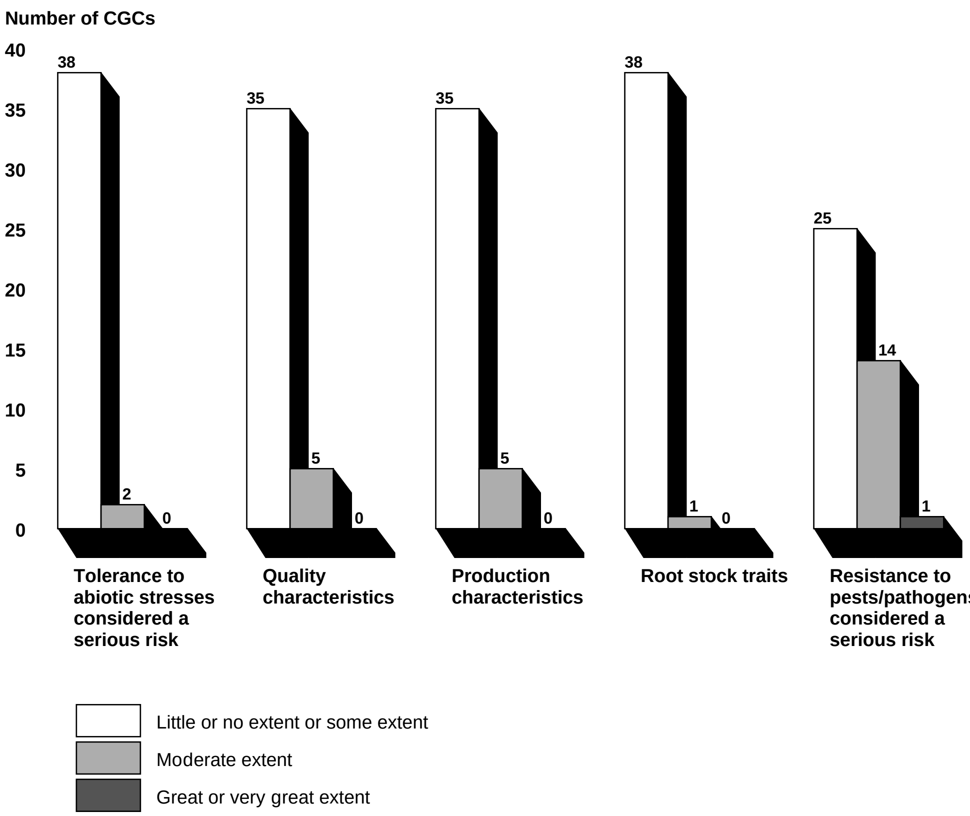
Figure 3.1: CGCs' Perceptions of the Sufficiency of Evaluation Information for Crop Breeding



The CGCs reported that the trait most likely to have been evaluated—of the five traits we asked for their views on—is "resistance to pests and pathogens considered to be a serious risk." Even so, less than half the CGCs reported that their germplasm has been evaluated to a moderate extent for this trait and only one to a great extent. For the remaining four evaluation traits, 35 to 38 CGCs reported their germplasm had been evaluated only to some, little, or no extent. These traits include tolerance to abiotic stresses, such as salt or drought, considered a serious risk; quality characteristics, such as flavor or appearance; production characteristics, such as yield;

and root stock traits.[2] (See fig. 3.2.) While identifying shortcomings in the evaluation information, almost half of the CGCs said that NPGS' management of evaluation data has improved since about 1990. (In addition, 20 CGCs said that there has been no change, and 1 said it has worsened.)

Figure 3.2: CGCs' Assessment of the Extent to Which Major Traits Have Been Evaluated



Note: One CGC did not respond to the question regarding root stock traits.

Almost Half the CGCs Reported That Characterization Information Is Insufficient

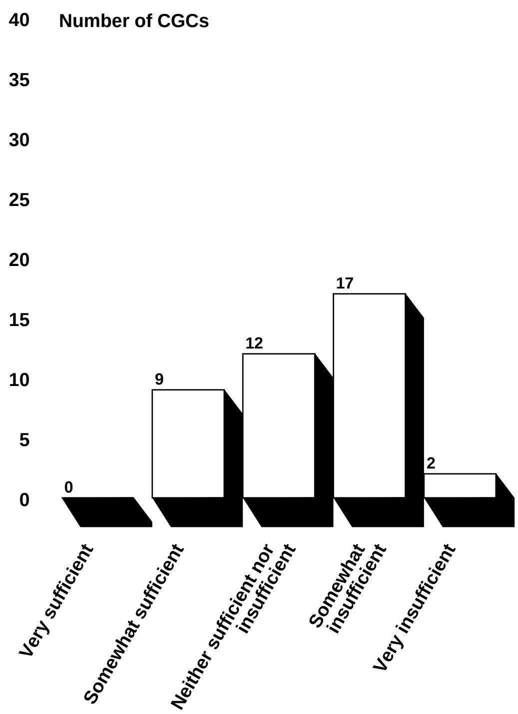
Characterization data provide information on highly inheritable traits that are little influenced by varying environmental conditions. These data help distinguish germplasm samples of the same type of plant from one another and provide a baseline for ensuring that the genetic integrity of a

[2]Root stocks are used in grafting clonal crops.

germplasm sample is maintained.[3] It is generally the responsibility of NPGS curators to develop characterization information when they regenerate germplasm samples.

Nineteen of the 40 CGCs reported that characterization information on their NPGS germplasm is somewhat or very insufficient for crop breeding. These 19 CGCs included some economically important crops, such as cotton, grapes, and peanuts. Only nine CGCs reported that characterization information for their crops' germplasm is somewhat sufficient for breeding. Figure 3.3 shows the sufficiency of characterization information, as reported by the CGCs. In addition, over half the CGCs said that NPGS' management of characterization data has improved since 1990.

Figure 3.3: CGCs' Perceptions of the Sufficiency of Characterization Information for Crop Breeding



[3]During germplasm regeneration, considerable care must be taken to minimize genetic shifts to the resulting seeds, or offspring. Genetic markers measured in characterization can be used to determine whether shifts have occurred.

Most CGCs Reported That Passport Information Is Sufficient for Crop Breeding, but NPGS Managers Said It Is Inadequate for Their Purposes

Passport information includes the data on the plant's classification, the location of the germplasm sample's origin, and the ecology of that location. This information is essential for assessing the quality of the collections and for using and managing these collections.[4] NPGS uses the data to ensure, for example, that it does not unnecessarily collect samples that have previously been collected from the same location.[5] Passport data are generally the first data obtained on a new germplasm sample and are often provided by the donor when the germplasm is given to NPGS. However, much germplasm is donated to NPGS without complete passport information.[6]

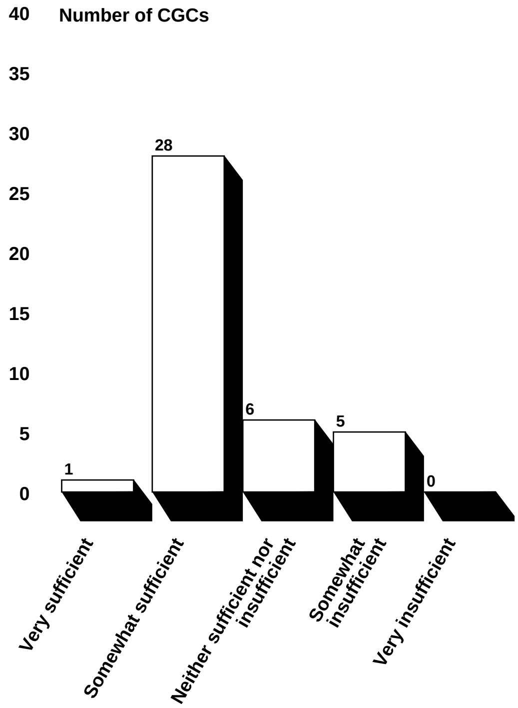
Although NPGS' passport information may be incomplete, the CGCs were considerably more positive about the passport information than about either evaluation or characterization information. As shown in figure 3.4, almost three-quarters of the CGCs reported that passport information for their crops is somewhat or very sufficient for crop-breeding purposes. Only five CGCs reported passport information to be somewhat insufficient for breeding.

[4] Managing Global Genetic Resources: Agricultural Crop Issues and Policies, National Research Council (Washington, D.C.: National Academy Press, 1993).

[5] On the other hand, NPGS may use passport data to resample rich areas or to recover lost samples from the same location.

[6] For older samples, this information will likely be unobtainable for various reasons—e.g., the original collector did not provide it or no other relevant records are available.

Figure 3.4: CGCs' Perceptions of the Sufficiency of Passport Information for Crop Breeding



Furthermore, three-quarters of the CGCs said that NPGS' management of passport data has improved since about 1990.

Although most CGCs found passport information to be somewhat or very sufficient for crop-breeding purposes, NPGS officials told us that it is not sufficient for their internal planning for germplasm acquisition. About two-thirds of NPGS' samples lack passport data on the location of origin, according to the GRIN data provided by NPGS officials. This information is key to pinpointing areas where germplasm has already been collected, thereby minimizing the possibility of unnecessarily collecting material already in the NPGS collection. Origin information also assists in targeting sites for future collection trips. Furthermore, according to NPGS officials, even when location information is available, it is sometimes inaccurate or incomplete. GRIN data, for example, show that 90 percent of NPGS' samples have no information on the latitude and longitude of the site of origin.

Incomplete passport information also makes it more difficult for curators to determine which samples are unique and which are duplicates.[7] Identification of duplicate samples is necessary to avoid needless duplication of costly germplasm-related activities, such as preservation, characterization, and evaluation. Curators for about half of the crop collections reported that it is moderately to extremely important to decrease the duplication of samples in their NPGS collection. For example, the sorghum curator estimated that about 10 to 25 percent or more of the samples in the sorghum collection are duplicates. He added that the elimination of these duplicates would be expensive and time-consuming because many samples lack complete passport data.

Needed Information Is Not Available for Several Reasons

While some information has not been developed because of resource constraints, even data that have been developed have not always been entered into GRIN. NPGS officials told us that developing, obtaining, and documenting information in GRIN are lower priorities than preserving the germplasm collections, and in some cases, these activities are outside the system's control.

Some Information Has Not Been Developed or Entered Into the Database

Thirty-nine CGCs estimated that, on average, 50 percent of existing, useful evaluation data on their collections are not in GRIN.[8] According to the NPGS managers of several sites and ARS officials who oversee crop-specific research programs, gaps in evaluation data for NPGS germplasm result from a variety of factors, including the large amount of germplasm that needs to be evaluated, the resource-intensive nature of evaluations, and limited resources. In addition, most germplasm evaluations are conducted outside of NPGS, primarily by ARS and university scientists who do not always provide NPGS with the resulting information for entry into GRIN. Thus, even when evaluation data exist, they are not always available through GRIN. Some scientists who conduct germplasm evaluations are funded by ARS and are required to submit their evaluation results to NPGS. However, other scientists, not funded by ARS, conduct evaluations as part of their larger research objectives. According to a former National Program Leader for Plant Genetic Resources, some of these evaluations merit inclusion in

[7]Curators responding to GAO's survey were more negative regarding passport information than the CGCs. Curators on 15 CGCs found passport information insufficient for their crops; curators on 18 CGCs found it sufficient. On the CGCs that had strong differences of opinion among members, curators may have focused on a different aspect of the information (e.g., taxonomy versus site of origin) than other CGC members.

[8]Members of one CGC provided no estimate.

GRIN; however, he said that NPGS does not have a clear policy on the curators' responsibility in obtaining this information.

Several CGC reports developed for NPGS have identified the need to enter additional evaluation information into GRIN. For example, the 1996 corn CGC report stated that much evaluation data had accumulated without being entered into GRIN or otherwise disseminated. Furthermore, according to the 1996 CGC report for cucurbits (e.g., squash, watermelon, cucumbers), NPGS has had relatively few requests for watermelon germplasm, in part because of the lack of relevant evaluation data in GRIN.

In addition, NPGS does not have a process for tracking whether scientists under agreement with ARS to evaluate NPGS germplasm have submitted evaluation data for entry into GRIN. As a result, NPGS has little assurance that the results of these ARS-supported evaluations are entered into GRIN. While several NPGS managers said they believe that most of this information is in GRIN, NPGS is nonetheless developing a system to track the information. The system is expected to be completed by early 1998.

Finally, some passport information—for example, the location of origin—cannot be developed because the germplasm samples were provided many years ago, and it would be very difficult or impossible to reconstruct the missing data. In addition, some passport information may be available but has not been added to GRIN. Although GRIN may not have complete data, 36 CGCs reported that it effectively provides information about their NPGS germplasm collections. Thirty-seven CGCs reported that NPGS' management of GRIN had improved since about 1990, making it the NPGS activity that was cited most frequently as having improved.[9]

Several NPGS Managers Stated That Maintaining Germplasm Viability Is a Higher Priority Than Information-Related Activities

According to several NPGS officials responsible for managing germplasm activities, preserving germplasm to keep it viable is of more fundamental importance than developing information and making it available. In addition, the total number of germplasm samples in NPGS' collections has increased about 29 percent from 1986 through 1996, according to the GRIN data provided by an NPGS official. With larger collections come greater demands on curators' time and resources. Therefore, the development and documentation of characterization information, which is done primarily by NPGS curators, occurs only as time permits. A case in point is the cucurbit collection. The CGC for cucurbits reported that characterization and

[9]CGCs were asked how much NPGS management of 13 activities had improved or worsened since about 1990.

evaluation information is insufficient for breeding of its crops. However, the curators for these crops reported that some cucurbit regeneration backlogs had increased and that between 5 and 40 years would be required to regenerate various parts of this collection given current resources.

Preservation Activities Have Not Kept Pace With Needs of the Collection

Preservation activities—including viability testing, germplasm regeneration, and secure, long-term backup storage of germplasm—have not kept pace with the preservation needs of the collections. First, only minimal viability testing—testing that determines the amount of live germplasm in a sample—has been conducted at some sites, including two plant introduction stations that account for over one-fourth of NPGS' germplasm samples. Viability testing is needed to determine when germplasm should be reproduced to prevent the loss of the sample. Second, NPGS has significant backlogs for regenerating germplasm at all four plant introduction stations. Regeneration—reproducing germplasm to obtain sufficient numbers of viable seeds—is essential, particularly when viability is known to be low or has not been tested. Third, over one-third of NPGS' germplasm is not backed up in NPGS' National Seed Storage Laboratory (NSSL), which provides secure, long-term storage for the system. Germplasm that is not backed up at NSSL is at greater risk of being lost.

Much Germplasm at Two Major Locations Has Not Been Tested for Viability

NPGS' standards require that viability testing be conducted as often as is needed for each species. Managers of three plant introduction stations stated that the germplasm in their collections should be tested every 5 to 10 years, depending on the species and the storage conditions for the germplasm.[1] Viability testing is important to determine when the sample is at risk of being lost.

According to NPGS data and NPGS officials, the amount of testing at some locations—including two of the four plant introduction stations—is insufficient. These two stations account for more than one-quarter of NPGS' active collection. The stations—in Griffin, Georgia, and Pullman, Washington—had tested less than one-fourth of their germplasm from 1986 through 1996.[2] A curator at the Griffin station cited a specific consequence of the failure to test for viability on a regular basis—all 10 samples of recently tested butternut squash were dead. The collection had previously not been tested for many years. As a result, he feared that much or all of this collection of about 500 samples—the only one of its kind in NPGS—may be dead.

[1]Viability testing is conducted primarily on seeds because the viability of clonal material can generally be determined by observation. The leader of the Geneva Plant Introduction Station stated that in the future this site's germplasm will need to be tested only every 10 to 30 years because the collection is now stored at about –18 degrees Celsius.

[2]In contrast, at the two other stations—Ames, Iowa, and Geneva, New York—about 60 percent or more of the germplasm had been tested for viability in the past 10 years.

While agreeing that viability testing is important, the Griffin and Pullman station managers told us that, given their large regeneration backlogs, focusing their limited resources on regeneration to maintain germplasm viability is more likely to save diversity in the germplasm collections than testing the germplasm. Other obstacles cited as reasons for infrequent testing include the large numbers of different species to test and the lack of testing methods for some of them.

NSSL also conducts viability tests on the germplasm it maintains in long-term storage. At NSSL, 82 percent of its samples have been tested, 69 percent from 1985 through 1996. Of the 18 percent never tested, 61 percent do not have enough seeds for testing,[3] and 39 percent are part of a backlog that has not yet been processed because of the lack of resources, according to NSSL data and NPGS officials.

While NPGS' data indicate that viability testing is not conducted as often as it should be, responses to our survey on the sufficiency of viability testing were mixed. Only 4 of the 40 CGCs we surveyed reported that NPGS' viability testing activities are insufficient for their crops, although 29 indicated that the current staff levels for testing (as well as for regeneration) have hindered the preservation of their collections. However, when we examined the responses of the curators alone—who are responsible for maintaining and preserving the collections and are most knowledgeable about their condition—curators for part or all of 16 of 38 crop collections (including major crops such as corn, alfalfa, and cotton) reported that viability testing for their crop collections is insufficient.[4] For example, the curator responsible for over 80 percent of the corn collection reported that regeneration and viability testing are somewhat insufficient and should be the first priority in case of additional funding.

NPGS Has Significant Backlogs of Germplasm Requiring Regeneration

Regeneration is necessary to ensure that NPGS has an adequate supply of viable seeds. NPGS generally schedules a sample for regeneration when the viability of the sample is low—i.e., more than 35 percent of the sample's seeds are dead—or the quantity of seeds is too low for distribution. NPGS has significant backlogs of germplasm requiring regeneration. According to NPGS officials, large backlogs may cause the loss of diversity in collections or prevent distribution to users and to NSSL for secure backup.

[3]Some of these are seeds of special genetic stocks that will be used in research and should not be sacrificed for germination tests.

[4]Curators for two CGCs reported having no basis to judge. In addition, 15 CGCs have multiple curators on their committees, each of whom is responsible for parts of the collection.

NPGS officials from two plant introduction stations told us that, generally, their sites' germplasm that is low in viability or quantity should be regenerated within 2 to 5 years in order to minimize the loss of diversity in their collections over the long term. However, it may take as much as 75 to 100 years for the samples at these two locations that need regenerating to be regenerated, according to NPGS curators. Table 4.1 shows the estimated number of years required to regenerate samples, at current resource levels, for various crops at the four plant introduction stations, as of Spring 1997. Some of these years are underestimated because they do not include the regeneration that would be required to provide germplasm for secure backup to NSSL and material to users that has been correctly regenerated.[5]

Table 4.1: Estimated Years Required to Regenerate the Samples of Major Seed Crops at the Plant Introduction Stations at Current Resource Levels

Plant introduction station	Total number of major seed crops	Total number of samples in these crops	Percent of these samples requiring regeneration	Range of years required to regenerate samples	Median years required to regenerate samples
Ames, Iowa	10	35,300	35	5-23	10
Geneva, New York	6	8,900	35	3-20	5
Griffin, Georgia	9	63,690	16	5-100	10
Pullman, Washington	17	63,932	51	3-75	7

Notes: Major seed crops are those representing the station's largest collections. Although these data are primarily for seed crops, a small number of clonally propagated samples are included. In addition, sites did not provide estimates for the years required to regenerate the samples for a few crops.

Source: Estimates were provided by each of the four plant introduction stations.

As table 4.1 shows, of the four plant introduction stations, the Pullman, Washington, location has the biggest backlog in terms of the percentage of samples requiring regeneration. Such regeneration is important not only for preservation of diversity but also for supplying seed to NSSL for long-term, secure backup.

[5]According to NPGS officials, in past decades germplasm in some collections was regenerated incorrectly because of inadequate curatorial knowledge, adverse environmental conditions (e.g., hail, windstorm), or lack of resources. For example, some germplasm was regenerated with an insufficient plant population and some without controlling pollination to prevent contamination from other plants. NPGS officials believe that practices involving human error have largely been eliminated. However, some of this germplasm still needs to be replaced through regeneration using correct methods.

Several factors contribute to these backlogs. The biggest single factor is the limited number of permanent employees and seasonal laborers available to manage and carry out the necessary field and greenhouse activities, according to NPGS officials. Furthermore, at some locations, facilities for regeneration are inadequate, and at others the growing conditions for germplasm are less than ideal for producing good yields of high-quality seed.[6] For some collections, these regional climatic conditions also contribute to the development of pests and pathogens, which can hinder the preservation and use of germplasm.[7] To overcome these problems and increase its capacity to regenerate quality seed, NPGS recently established a new site—at Parlier, California—that is in an arid region with a long growing season. The Department has requested increased funding for genetic resources research in the fiscal year 1998 budget, part of which is to increase regeneration capability, according to an NPGS official.

CGC responses to our survey regarding the sufficiency of regeneration activities were similar to those on viability testing. Only 7 of the 40 CGCs we surveyed reported that NPGS' regeneration activities are insufficient for their collections, although 29 CGCs reported that the lack of staff for regeneration and viability testing had hindered the preservation of their collections. When we examined the responses of the curators (those most knowledgeable about the collections' conditions), curators for part or all of 15 of 39 crop collections reported that regeneration is insufficient for part or all of their crop collections.[8] The curator responsible for most of NPGS' corn collection reported that regeneration is insufficient and that the 15-year regeneration backlog for corn placed an important part of this collection at the risk of losing diversity.

Much Germplasm Is Not in Long-Term Backup Storage

Although NPGS' policy requires that all seed samples in active collections be backed up at NSSL, over one-third are not. Furthermore, methods to ensure the secure backup of most clonal germplasm have not yet been developed. Backup is needed to provide protection against losses at the active sites resulting from (1) deterioration, which generally occurs more

[6]Curators for part or all of 16 of 40 crop collections—including corn and tomato— reported that the ability to produce high-quality seed or maintain clonal crops at present sites hindered the preservation of their collections.

[7]Curators for part or all of the 14 crop collections reported that the ability to test for and maintain pathogen-free collections hindered the preservation of their collections.

[8]Curators for one CGC reported having no basis to judge in response to this question.

rapidly in seeds stored at active sites, or (2) human error, extreme weather, equipment failure, flood, fire, vandalism, or other catastrophes.

Sixty-one percent of the approximately 440,000 seed samples at NPGS' active sites are backed up at NSSL, where they are stored at –18 degrees Celsius or in containers over liquid nitrogen to slow deterioration.[9] Of these backed-up samples, 44 percent do not meet NPGS' standards and goals for the quantity of seeds and the percentage that should be viable—65 percent. The seed samples not stored at NSSL are at increased risk of deterioration because seeds generally deteriorate much more rapidly at active sites, which generally store germplasm at warmer temperatures—5 degrees Celsius.[10]

According to NPGS officials, seeds have not been adequately backed up primarily because of the large regeneration backlogs at active sites. That is, until the sites regenerate germplasm, they often do not have a sufficient number or quality of seeds to send to NSSL for backup storage. In addition, even when they have sufficient quantities of seeds, some sites have not sent the seeds to NSSL because before they can be sent, the sites must reinventory the germplasm samples and repackage the seeds. According to NPGS officials, these activities use resources that are in short supply. In addition, NSSL has its own 16-month backlog of about 27,000 samples that must be processed (which includes viability testing) before being placed in secure, long-term storage.

The backup of clonal samples is even more limited, with only 4 percent of the approximately 30,000 samples at the active sites backed up at NSSL. This limited backup occurs because the methods for providing secure, long-term storage for most clonal germplasm have not yet been developed.[11] Clonal germplasm may be backed up—in greenhouses as living plants, as tissue culture, or through cryopreservation—at the active site where the primary collection is maintained. Thus, in case of a natural disaster, disease, or other catastrophe, both the active and backup samples could be destroyed. For example, in 1992, over 2,000 germplasm samples were lost at NPGS' Miami facility following Hurricane Andrew. These samples were not backed up at another NPGS site or at NSSL. Included

[9]According to the director of NSSL, a higher percentage of the germplasm of the 50 most important crops is backed up.

[10]While plant introduction stations have recently acquired some –18 degrees Celsius storage capacity, most of their germplasm is still stored at 5 degrees Celsius.

[11]According to ARS' Assistant Administrator for Genetic Resources, research on methodologies for clonal crop cryopreservation will be NSSL's highest research priority if new funding is made available.

in this group were about 30 percent of the mango and avocado collections and about 50 percent of the site's ornamental collection (e.g., palm trees). The storm uprooted the trees, and they could not be successfully replanted. The curator for these crops stated that most of this material will not be replaced because of resource constraints, difficulties in locating the material, and difficulties in getting foreign collections to provide replacement samples.

CGC responses to our survey regarding the sufficiency of backup storage of germplasm varied. Only 6 of the 40 CGCs surveyed reported that NPGS' activity in the area of backup storage/preservation is insufficient for their crop collections. In contrast, the curators for part or all of 15 of 40 crop collections reported that NPGS' activity in the area of backup storage/preservation of their crop collection is insufficient.[12] The curators for the collections of six major crops—corn, soybeans, wheat, alfalfa, potato, and cotton—reported no insufficiencies in this area.

[12]Curators for nine collections—including citrus fruits, peanuts, and sugarcane—indicated that backup was insufficient for their collections overall.

Survey Methodology

We surveyed crop germplasm experts identified by NPGS. These experts included the 542 members of 40 Crop Germplasm Committees (CGCs), including all NPGS curators and CGC chairs; 27 recently retired CGC members; and 38 experts who were not serving on a CGC. Forty-five of those surveyed served on more than one CGC and were asked to complete one survey for each CGC on which they served. For the purposes of our survey, experts not currently serving on a CGC were assigned membership on the CGC that represented their area of expertise. In all, we mailed questionnaires to 680 CGC "members"—one questionnaire to each of the 562 members serving on one CGC and 118 questionnaires to the 45 experts serving on more than one CGC. We followed up this initial mailing with additional mailings and telephone calls to encourage response. We conducted our survey from November 1996 through March 1997.

We received a total of 576 usable questionnaires, including responses from all the NPGS curators, for a response rate of 85 percent. Only two CGC chairs did not participate in the survey (alfalfa and small fruits). Response rates varied across CGCs, from a low of 57 percent for the vigna and pepper CGCs to a high of 100 percent for three CGCs (corn, sugarbeets, and tobacco). Response rates were above 70 percent for all but four CGCs (cotton, new crops, peppers, and vigna). The median response rate for CGCs was 86 percent.

We analyzed the survey results by CGC. To obtain a single CGC response for each question, we aggregated the responses of the CGC members on that committee. We performed this aggregation by first selecting only those CGC members who had a substantive opinion on a particular question (that is, the member did not select "no basis to judge" as his or her response). We did not use the opinion if the question asked about the entire NPGS collection but the respondent answered for only a minor portion of the collection, unless the respondent was an NPGS curator. The selected members' responses were aggregated by using one of three statistics, depending on the type of question. The mean response was used for questions requiring a numeric response. (See, for example, app. II, questions 12 and 44.) The median response was used for questions requiring an evaluation of the NPGS collection or NPGS management. (See, for example, app. II, questions 7 and 42.) When the median was between two rating categories, we reported the results in the category with the lower intensity. For questions that required the respondent to sort information into nonnumeric, nonrating categories, we used the percentage of CGC members who selected each category to represent the CGC response. (See, for example, app. II, question 11.)

Appendix II contains a copy of our survey with the results aggregated by CGC. In order to report the data completely and show instances in which the median was between two rating categories, we altered the original format of the questionnaire by deleting the response option "no basis to judge" from questions 17 and 18 and changing the size of the response boxes for these and several other questions. We used the letter "t" to indicate the number of medians that were between a given category and the next most intense category for that question.

Results of GAO's Survey of Crop Germplasm Committees

United States General Accounting Office

GAO

Survey of Crop Experts on the National Plant Germplasm System

Introduction

The U.S. General Accounting Office is reviewing the management of the National Plant Germplasm System (NPGS) and its effectiveness in reducing crop vulnerability and increasing crop productivity. As part of our review, we are surveying members of all Crop Germplasm Committees and other crop experts. We are interested in your assessment of the current NPGS and your opinions about what its priorities for the future should be.

Your participation in our survey is essential in order for us to present to the U.S. Congress a balanced view of the NPGS. Thank you for your cooperation.

Instructions

Please limit your responses to the crops covered by the Crop Germplasm Committee (CGC) named on the label below. If your committee covers more than one crop, please respond overall for the entire group of crops.

If possible, please return your completed survey in the enclosed envelope within two weeks. This will help us avoid costly follow-up. The return address is:

Ms. Sonja Bensen
U.S. General Accounting Office
441 G Street, N.W., Room 1826
Washington, D.C. 20548

→→*Analysis Note:* **Reported frequencies are median responses of members of each CGC; percentages are the mean percentage across all CGCs; and averages are the mean of the CGC means. Medians that are between two categories are reported in the less intense or more neutral category and indicated with a "t."**

Definitions

NPGS (National Plant Germplasm System): The coordinated efforts of the

- National Germplasm Resources Laboratory at Beltsville, including the Quarantine Center;
- Plant Introduction Stations at Geneva, Griffin, Ames, and Pullman;
- 10 National Clonal Germplasm Repositories;
- National Seed Storage Laboratory at Ft. Collins; and
- Many crop-specific collections in universities and USDA laboratories (e.g., the National Small Grains Collection in Aberdeen, the Interregional Potato Project in Sturgeon Bay, the Cotton Collection in College Station, and the Soybean Collection in Urbana)

Background

1. Is the crop or crop group named on the label primarily seed propagated or clonally propagated for the purposes of storage and preservation? *(Check one.)* 1(5)

   24 Entirely or almost entirely seed propagated

   12 Entirely or almost entirely clonally propagated

   4 Both seed and clonally propagated

2. For how many years have you worked with and/or managed germplasm for the crop or crop group named on the label? *(Enter total years experience.)* (6-7)

   18.1 years, average across CGCs

1

3. What role, if any, do you currently have on the Crop Germplasm Committee named on the label on page one? *(Check one.)*

(8)

- 69 NPGS crop curator
- 38 Committee chair
- 419 Committee member
- 18 Former committee member
- 32 Expert added at request of NPGS
- 576 TOTAL

4. In which of the following areas do you perform work (or, if retired, did you perform work) related to germplasm for the crop or crop group named on page one? *(Check all that apply.)*

(9-31)

- 7% Biochemistry
- 10% Cytogenetics
- 12% Entomology
- 63% Genetics
- 39% Horticulture
- 20% Molecular biology
- 41% Plant pathology
- 17% Plant physiology

- 35% Acquisition activities
- 65% Breeding
- 31% Crop production
- 20% Curatorship
- 65% Evaluation and/or characterization
- 43% Prebreeding or enhancement
- 30% Research management
- ____ Other *(Please specify.)*

→→*Analysis Note:* **In question 7, "1t +29" means the median response for 1 CGC was between "very serious" and "moderately serious," while the median for 29 CGCs was "moderately serious." The note on the front page of the survey explains this further.**

5. Which of the following describes your current employer (or former employer, if retired) for the major portion of your work related to plant germplasm? *(Check all that apply.)*

(32-35)

- 11% Seed company
- 46% University
- 34% Agricultural Research Service (ARS)
- ____ Other *(Please specify.)*

6. While we prefer that you answer the questionnaire by averaging across the entire NPGS collection (including related accessions) for all crop(s) named on the page one label, you may not be able to do this. Please indicate below the basis on which you will answer the questions. *(Check one.)*

(36)

- 62% All crops and related accessions in the NPGS collection named on the label at all of their NPGS locations
- ____ All crops and related accessions in the NPGS collection named on the label, but not at all of their NPGS locations *(Please specify locations included in your response.)*
  Locations: ____________
- ____ Less than all of the crops and related accessions in the NPGS collection named on the label *(Please specify crops and locations included in your response.)* (37-41)

  Crops: ____________

  Locations: ____________

Vulnerability

7. Overall, for the crop or crop group named on the label on page one, how serious a problem, if at all, is genetic vulnerability? *(Check one.)*

(42)

- 0 Extremely serious problem
- 6 Very serious problem
- 1t+29 Moderately serious problem
- 2t+2 Somewhat serious problem
- 0 Hardly or not at all a serious problem
- ____ No basis to judge

2

8. To what extent, if at all, does the NPGS provide the needed germplasm and information on germplasm to respond to crises for this crop or crop group? *(Check all that apply.)*

(43-57)

Germplasm

0 Little or no extent
2+1t Some extent
12+1t Moderate extent
23 Great extent
1 Very great extent
____ No basis to judge

Information on germplasm

0 Little or no extent
10+3t Some extent
21+1t Moderate extent
5 Great extent
0 Very great extent
____ No basis to judge

9. In your opinion, how much genetic diversity, if any, is there in the U.S. planted acreage of this crop or crop group? *(Check one.)*

(58)

0 None
4+2t Little
20+2t Some
12 Moderate
0 Great
0 Very great

Diversity in the Collection

10. In your opinion, to what extent, if any, are there accessions that would increase the diversity of the NPGS collection for this crop or crop group that are not in the NPGS collection but should be placed there? *(Check one.)*

(59)

0 Little or no extent
3+1t Some extent
21+2t Moderate extent
13 Great extent
0 Very great extent
____ No basis to judge

11. Which, if any, of the following are the most important sources of germplasm that, if acquired, would increase the genetic diversity of the NPGS collection? *(Check all that apply.)*

(60-66)

79% Foreign collection trips
18% Domestic collection trips
63% Foreign institutions or breeders
29% International centers
22% U.S. university breeders' collections
18% U.S. private industry collections
3% Other *(Please specify.)*

12. Overall, about what percentage, if any, of the collected and freely available germplasm for this crop or crop group is represented in the NPGS collection? *(Enter percent or check "No basis to judge".)* (67-70)

60%, average across CGCs

____ No basis to judge

3

13. In your opinion, how sufficient or insufficient for reducing crop vulnerability is the genetic diversity of each of the following parts of the NPGS collection for this crop or crop group? *(Check one for each.)* (71-75)

	Very sufficient (1)	Some - what sufficient (2)	Neither sufficient nor insufficient (3)	Some - what insufficient (4)	Very insufficient (5)	No basis to judge (6)	Does not apply to this crop (7)
1. Obsolete and current cultivars (U.S. and foreign)	0	24	11	3+1t	1		
2. Landraces	0	1t+15	12	9	3		
3. Wild and weedy relatives	0	13	1t+5+3t	11+4t	3		
4. Genetic stocks (e.g., lines containing mutant alleles useful for research)	0	7	2t+8+1t	16+1t	5		
5. Other *(Please specify.)*							

14. In your opinion, how sufficient or insufficient, overall, for reducing crop vulnerability is the genetic diversity of the NPGS and all freely available collections for this crop or crop group? *(Check all that apply.)* 2(5-23)

NPGS collection

0 Very sufficient
22 Somewhat sufficient
1t+6+2t Neither sufficient nor insufficient
7 Somewhat insufficient
2 Very insufficient
____ Do not know the genetic diversity of the NPGS collection
____ No basis to judge

All freely available collections, including NPGS

1 Very sufficient
28 Somewhat sufficient
2t+2 Neither sufficient nor insufficient
7 Somewhat insufficient
0 Very insufficient
____ Do not know the genetic diversity of all collections
____ No basis to judge

15. How important, if at all, is it to increase the genetic diversity of the NPGS collection for this crop or crop group? *(Check one.)* (24)

1 Extremely important
25 Very important
4t+10 Moderately important
0 Somewhat important
0 Hardly or not at all important
____ No basis to judge

16. How important, if at all, is it to decrease duplication of accessions in the NPGS collection for this crop or crop group? *(Check one.)* (25)

0 Extremely important
2 Very important
13 Moderately important
5t+10 Somewhat important
2t+8 Hardly or not at all important
____ No basis to judge
____ Few, if any, duplicate accessions in the collection

4

17. A. How strongly do you agree or disagree with each of the following statements about this crop or crop group? B. To what extent, if at all, have each of the situations hindered the NPGS's ability to increase the genetic diversity of its collection for this crop or crop group? *(Check one for each row and question.)* (26-47)

	A. Agreement with Statement					B. Hindered NPGS' Ability To Increase Diversity				
	Strongly disagree (1)	Disagree somewhat (2)	Neither disagree nor agree (3)	Agree somewhat (4)	Strongly agree (5)	Little or no extent (1)	Some extent (2)	Moderate extent (3)	Great extent (4)	Very great extent (5)
1. Certain plants are becoming extinct or hard to find.	0	0	1+2t	25+3t	9	1	18+6t	14	1	0
2. Few scientists are available or willing to make needed collection trips.	1	1t+11	2t+6+2t	16	1	12+5t	12+3t	8	0	0
3. Costs of needed collection trips are high.	0	0	7	21+4t	8	0	10+5t	18+1t	6	0
4. Knowledge about deficiencies in the genetic diversity of the collection is limited.	0	2	4+3t	27	4	0+1t	16+6t	14+3t	0	0
5. Some U.S. breeders are not willing to share germplasm with NPGS.	9	2t+17	6+3t	3	0	21+6t	11+1t	1	0	0
6. Some U.S. curators are not willing to share germplasm or coordinate with NPGS.	33	2t+4	1	0	0	38+1t	1	0	0	0
7. There are uncertainties over ownership of germplasm and intellectual property rights.	1	1	2t+6+5t	23+1t	1	5+3t	23+4t	5	0	0
8. Foreign countries' fees and requirements for U.S. collection trips have become more burdensome.	0	2	1t+8+4t	23	2	3+2t	14+6t	11	4	0
9. Foreign countries have restricted access to certain geographic areas.	0	1	3+1t	26+2t	7	0+1t	13+6t	13+2t	4	1
10. There are longstanding political difficulties in acquiring germplasm from foreign countries.	0	0	1t+6+2t	25+2t	4	0+1t	10+3t	21+1t	4	0
11. Other *(Please specify.)*										

→→***Analysis Note:*** The "No Basis To Judge" option was deleted from Q.17 and Q.18 to display the results.

5

18. A. In your opinion, how effectively or ineffectively has the NPGS performed each of the following activities for this crop or crop group? B. In your opinion, how much should USDA increase or decrease their emphasis on each of them in the future for this crop or crop group? *(Check one for each row and question.)* (48-71)

	A. Effectiveness					B. Future Emphasis				
	Very effectively (1)	Somewhat effectively (2)	Neither effectively nor ineffectively (3)	Somewhat ineffectively (4)	Very ineffectively (5)	Greatly increase (1)	Somewhat increase (2)	No change (3)	Somewhat decrease (4)	Greatly decrease (5)
1. Plan acquisitions for this crop or crop group	2	1t+19	5t+10+1t	2	0	4	2t+33	1	0	0
2. Systematically implement acquisition planning	1	11	2t+18+1t	6	1	4	1t+35	0	0	0
3. Develop origin/passport data to assist in planning	2	21	1t+12+3t	1	0	1	33	6	0	0
4. Use geographic mapping technologies to identify potential sites for collection	0	5	2t+23+3t	6	1	0	4t+28	2t+6	0	0
5. Acquire information and/or links to other U.S. collections	1	4t+18	6t+6+1t	4	0	2	20	2t+16	0	0
6. Acquire information and/or links to foreign collections	1	1t+16	4t+14+1t	2	1	6	1t+32	1t+0	0	0
7. Conduct quarantine activities to facilitate acquisition	2	13	5t+10+4t	4+1t	1	6	1t+12	2t+19	0	0
8. Use political efforts to attempt to improve U.S. access to foreign germplasm	0	2	2t+25+5t	6	0	2	2t+29	5t+2	0	0
9. Work cooperatively with foreign institutions and individuals to identify and acquire germplasm	2	25	3t+8	2	0	8	31	1t+0	0	0
10. Acquire germplasm endangered in nature or collections at risk (e.g., Vavilov or collections of scientists who are retiring)	0	1t+14	5t+15+2t	2	1	8	6t+25	1	0	0
11. Preserve NPGS germplasm that has been classified as at-risk by NPGS	1	26	4t+7+1t	1	0	5	3t+25	2t+5	0	0
12. Other *(Please specify.)*										

6

Quarantine

19. Is this crop or crop group subject to federal quarantine testing or restrictions upon entering the U.S.? *(Check one.)* (72)

____ Yes →*Please continue.*

____ No →*Skip to Question 22*

→Analysis Note: Frequencies do not add up to 40 for Questions 20 and 21 because some CGCs had no experience.

20. In your opinion, how effective or ineffective have U.S. quarantine regulations and processing been in each of the following areas for this crop or crop group? *(Check one for each.)* (73-76)

	Very effective (1)	Somewhat effective (2)	Neither effective nor ineffective (3)	Somewhat ineffective (4)	Very ineffective (5)	No basis to judge (6)
1. Reducing the introduction of pests and pathogens	10	5t+19	1t+2	1	1	
2. Timely release of germplasm	1	3t+11	5t+6	8	5	
3. Release of viable germplasm	2	2t+13	3t+13+1t	4	1	
4. Other *(Please specify.)*						

21. How much, if at all, have each of the following federal quarantine-related factors helped or hindered timely acquisition of viable germplasm for this crop or crop group? *(Check one for each.)* 3(5-14)

	Greatly helped (1)	Some-what helped (2)	Neither helped nor hindered (3)	Some-what hindered (4)	Greatly hindered (5)	No basis to judge or no experience (6)
1. Extent of coordination between ARS and APHIS (Animal and Plant Health Inspection Service)	2	12	1t+12+2t	5+1t	0	
2. Consistency of information provided by ARS and APHIS	0	12	2t+12+2t	8	0	
3. Current required testing procedures	0	3	2t+13+1t	11+3t	2	
4. Reliability of test results	0	8	5t+15+2t	5	0	
5. Process used to decide when to release a quarantined accession	0	5	3t+14+4t	6+1t	0	
6. Suitability of quarantine facilities and/or sites for plant growth	2	4	3t+9+1t	11+1t	1	
7. Crop production practices during quarantine	0	2	5t+14	8	3	
8. Adequacy of pest/pathogen eradication during quarantine	2	1t+10	1t+13+2t	3+1t	0	
9. Management of the process	0	6	4t+10+1t	9	4	
10. Other *(Please specify.)*						

7

Information on the NPGS Collection

Origin/passport: Information about germplasm, such as taxonomy, location and ecological conditions of the site of origin, and plant introduction number

Characterization: Assessment of traits that are *little influenced by varying environmental conditions* (e.g., morphological descriptors and molecular markers)

Evaluation: Assessment of plants for potentially useful traits, *many of which may be environmentally influenced*

22. How important to you, if at all, are each of the following types of information on NPGS accessions for this crop or crop group? Please refer to the definitions provided above. *(Check one for each.)* (15-17)

	Hardly or not at all important (1)	Somewhat important (2)	Moderately important (3)	Very important (4)	Extremely important (5)
1. Origin/passport information	0	0	4+1t	26+2t	7
2. Characterization information	0	0	1+4t	28+3t	4
3. Evaluation information	0	0	1+1t	21+4t	13

23. In your opinion, how sufficient or insufficient are each of the following types of information on NPGS's germplasm collection for enhancement and breeding of this crop or crop group? *(Check one for each.)* (18-20)

	Very sufficient (1)	Somewhat sufficient (2)	Neither sufficient nor insufficient (3)	Somewhat insufficient (4)	Very insufficient (5)	No basis to judge (6)
1. Origin/passport information	1	1t+27	6	5	0	
2. Characterization information	0	9	9+3t	16+1t	2	
3. Evaluation information	0	3	1t+5+1t	19+1t	10	

8

24. Overall, to what extent, if at all, has this crop or crop group's NPGS germplasm been **evaluated** for each of the following? *(Check one for each.)* (21-26)

	Little or no extent (1)	Some extent (2)	Moderate extent (3)	Great extent (4)	Very great extent (5)	No basis to judge (6)	Does not apply to this crop (7)
1. Resistance or susceptibility to pests and pathogens considered a serious risk	2	20+3t	13+1t	1	0		
2. Tolerance to abiotic stresses considered a serious risk (e.g., salt tolerance, drought resistance)	18+4t	16	2	0	0		
3. Quality characteristics (e.g., flavor, appearance, storage, texture)	10+1t	23+1t	5	0	0		
4. Production characteristics (e.g., yield, time to maturity, years to production)	9+1t	22+3t	5	0	0		
5. Root stock traits	20+5t	12+1t	1	0	0		
6. Other *(Please specify.)*							

25. With regard to **evaluation** of NPGS's collection for this crop or crop group, how sufficient or insufficient are each of the following? *(Check one for each.)* (27-33)

	Very sufficient (1)	Some - what sufficient (2)	Neither sufficient nor insufficient (3)	Some - what insufficient (4)	Very insufficient (5)	No basis to judge (6)
1. Current status of determining and prioritizing which descriptors are important to users	2	2t+22	1t+8+2t	2+1t	0	
2. Current status of the development of standardized evaluation procedures	1	1t+14	1t+14+1t	7+1t	0	
3. Number of qualified scientists currently available to evaluate germplasm	0	2	2t+4	25+2t	5	
4. Amount of NPGS resources currently provided for evaluation	0	0	1t+0+1t	23+3t	12	
5. Amount of USDA, non-NPGS, resources currently provided for evaluation	0	0	1	23+4t	12	
6. Amount of state resources currently provided for evaluation	0	0	0	12+6t	22	
7. Other *(Please specify.)*						

9

Germplasm Resources Information Network

26. How often, if at all, do you use the Germplasm Resource Information Network (GRIN)? *(Check one.)* (34)

____ Once every few years, if ever→*Skip to Q.30*

____ About once a year→*Skip to Q.30*

____ Several times a year→*Please continue*

____ About once a month→*Please continue*

____ Daily or weekly →*Please continue*

44% , on average, answered "several times a year" to "daily or weekly"

27. About what percentage of existing useful evaluation data on the NPGS collection for your crop or crop group is in GRIN? *(Enter percent or check one.)* (35-38)

50%, average across 39 CGCs; 1 No estimate

28. In your opinion, overall, how effective or ineffective is GRIN in providing information about the NPGS collection for this crop or crop group? *(Check one.)* (39)

6 Very effective

4t+26 Somewhat effective

1t+0 Neither effective nor ineffective

2 Somewhat ineffective

1 Very ineffective

29. In your opinion, how effective or ineffective are each of the following aspects of the version of GRIN in operation after January 1, 1996? *(Check one for each.)* (40-43)

	Very effective (1)	Somewhat effective (2)	Neither effective nor ineffective (3)	Somewhat ineffective (4)	Very ineffective (5)	Not familiar with GRIN (6)
1. Search function	4	6t+28	1t+1	0	0	
2. User-friendliness of the system	2	3t+26	2t+6	1	0	
3. Availability of GRIN when needed	19	4t+17	0	0	0	
4. Other *(Please specify.)*						

Preservation

30. In your opinion, how sufficient or insufficient is the NPGS' activity in each of the following preservation areas for the NPGS collection for this crop or crop group? *(Check one for each.)* (44-48)

	Very sufficient (1)	Somewhat sufficient (2)	Neither sufficient nor insufficient (3)	Somewhat insufficient (4)	Very insufficient (5)	No basis to judge (6)
1. Regeneration	2	24	1t+6	7	0	
2. Viability testing	2	1t+21	3t+8+1t	3	1	
3. Backup storage/preservation	3	22	3t+4+2t	6	0	
4. Preservation research	1	2t+9	4t+9+2t	10+3t	0	
5. Other *(Please specify.)*						

10

31. How much, if at all, have each of the following helped or hindered NPGS's preservation of this crop or crop group's germplasm collection? *(Check one for each.)* (49-59)

	Greatly helped (1)	Some - what helped (2)	Neither helped nor hindered (3)	Some - what hindered (4)	Greatly hindered (5)	No basis to judge (6)
1. Current preservation techniques	1	1t+25	5t+8	0	0	
2. Size, quality, and/or security of storage facilities for active sites	6	19	1t+12+1t	1	0	
3. Current number of staff for regeneration and viability testing activities	1	5	1t+4	26+2t	1	
4. Number of accessions in the collection	0	5	1t+17	17	0	
5. Ability to test for and maintain pathogen-free collections	0	2t+4	1t+25+1t	7	0	
6. Ability to produce high-quality seed or maintain clonal crops at present sites	3	12	5t+8+5t	6+1t	0	
7. Amount of training available for staff conducting preservation activities	0	13	4t+14+3t	6	0	
8. Current planning and prioritization of activities	1	15	6t+13+3t	1+1t	0	
9. Quarantine regulations and procedures	0	2	26+2t	6	4	
10. Amount of germplasm in backup storage	0	7	3t+24+2t	4	0	
11. Other *(Please specify.)*						

Use of NPGS Germplasm

32. To what extent, if at all, have you used germplasm from the NPGS collection for this crop or crop group for breeding and/or research? *(Check one.)* (60)

____ Little or no extent →*Skip to Q.35*
____ Some extent →*Please continue*
____ Moderate extent →*Please continue*
____ Great extent →*Please continue*
____ Very great extent →*Please continue*
____ Used as NPGS curator only →*Skip to Q.35*
75% , on average, answered "some" to "very great" extent

11

33. About what percentage of the germplasm you currently use did you acquire from each of the following sources? *(Enter percentages that sum to 100 percent.)* 4(5-28)

38% Your own germplasm collection

8% Foreign institutions or breeders' collections

3% International centers

12% U.S. university breeders' collections (not yours)

6% U.S. private industry collections (not yours)

27% NPGS collection

6% USDA, non-NPGS collections

1% Other *(Please specify.)*

100% TOTAL

34. How much, if at all, have each of the following helped or hindered your use of NPGS germplasm for this crop or crop group? *(Check one for each.)* (29-37)

	Greatly helped (1)	Some - what helped (2)	Neither helped nor hindered (3)	Some - what hindered (4)	Greatly hindered (5)	No basis to judge (6)
1. Completeness of the collection	2	1t+13	6t+8+2t	6	2	
2. Amount of origin/passport data	2	10	2t+18+3t	5	0	
3. Accuracy of origin/passport data	1	7	3t+24+2t	3	0	
4. Amount of characterization data	1	7	1t+14+3t	12+1t	1	
5. Amount of evaluation data in GRIN	0	4	2t+19+5t	10	0	
6. Amount of evaluation data anywhere	0	1t+2	1t+19+3t	14	0	
7. Viability of the accessions in the collection	4	17	3t+13+2t	1	0	
8. Availability of seed or germplasm	9	21	4t+4	2	0	
9. Other *(Please specify.)*						

12

Enhancement or Prebreeding: Incorporating desired traits of wild germplasm into a domesticated crop variety, so that the resulting variety will be suitable for elite cross-breeding.

35. In your opinion, are the resources devoted to enhancement or prebreeding of this crop or crop group by USDA, university, and other public sector breeders too much, too little or about the right amount? *(Check one.)* (38)

- 0 Definitely too much
- 0 Probably too much
- 0+2t About the right amount
- 16+2t Probably too little
- 20 Definitely too little
- ___ No basis to judge

Breeding Activity

36. In your opinion, are the resources devoted to breeding of this crop or crop group by USDA, university, and other public sector breeders too much, too little or about the right amount? *(Check one.)* (39)

- 0 Definitely too much
- 0 Probably too much
- 3+1t About the right amount
- 25+1t Probably too little
- 10 Definitely too little
- ___ No basis to judge

NPGS Management and Funding

37. Is there a core subset for this collection (i.e., a subset of the collection for a crop that contains much of the collection's diversity) for any of the crops in this crop group? *(Check one.)* (40)

- 31 Yes →*Please continue*
- ___ No →*Skip to Question 39*
- ___ Uncertain →*Skip to Question 39*

38. In your opinion, should the NPGS spend more or less time on improving the core subset for this crop or crop group? *(Check one.)* (41)

- 1 Much more time
- 4t+16 Somewhat more time
- 5t+3 No change
- 2 Somewhat less time
- 0 Much less time

39. In your opinion, how much would or will a core subset help or hinder each of the following for this crop or crop group? *(Check all that apply.)* (42-60)

Using the NPGS collection

- 3 Greatly help
- 27 Somewhat help
- 4t+6 Neither help nor hinder
- 0 Somewhat hinder
- 0 Greatly hinder
- ___ No basis to judge
- ___ Too early to tell

Managing the NPGS collection

- 4 Greatly help
- 1t+30 Somewhat help
- 2t+3 Neither help nor hinder
- 0 Somewhat hinder
- 0 Greatly hinder
- ___ No basis to judge
- ___ Too early to tell

13

40. With regard to this crop or crop group, overall, how satisfied or dissatisfied are you with the NPGS's management, given its resources? *(Check one.)* (61)

2 Very satisfied
1t+27 Generally satisfied
3t+7 Neither satisfied nor dissatisfied
0 Generally dissatisfied
0 Very dissatisfied

41. With regard to this crop or crop group, overall, how satisfied or dissatisfied are you with the resources USDA has provided for the NPGS? *(Check one.)* (62)

0 Very satisfied
1 Generally satisfied
3t+10+6t Neither satisfied nor dissatisfied
20 Generally dissatisfied
0 Very dissatisfied

42. In your opinion, for this crop or crop group, how much has NPGS management of each of the following activities improved or worsened since about 1990, or has there been no change? *(Check one for each.)* (63-76)

	Greatly improved (1)	Somewhat improved (2)	No change (3)	Somewhat worsened (4)	Greatly worsened (5)	No basis to judge (6)
1. Acquisition of germplasm	1	14	2t+22	1	0	
2. Development and documentation of origin/passport data	0	30	1t+9	0	0	
3. Development and documentation of characterization data	0	22	6t+11	1	0	
4. Development and documentation of evaluation data	0	19	20	1	0	
5. Germplasm Resources Information Network (GRIN)	6	1t+30	1t+2	0	0	
6. Distribution of germplasm	1	18	2t+19	0	0	
7. Regeneration and viability testing	1	1t+7	8t+23	0	0	
8. Active storage/preservation	0	23	4t+13	0	0	
9. Backup storage/preservation	1	19	1t+19	0	0	
10. Research on maintenance/preservation	1	3	2t+31	3	0	
11. Quarantine	0	4	1t+33	2	0	
12. Cooperation and working relationships with universities	0	20	19	1	0	
13. Coordination between NPGS curators and non-NPGS curators	0	16	3t+20+1t	0	0	
14. Other *(Please specify.)*						

14

43. In your opinion, does the NPGS provide too much, too little or about the right amount of funds for each of the following activities for this crop or crop group, given its current resources? *(Check one for each.)* 5(5-19)

	Definitely too much (1)	Probably too much (2)	About the right amount (3)	Probably too little (4)	Definitely too little (5)	No basis to judge (6)
1. Acquisition of germplasm	0	0	5+2t	30+1t	2	
2. Development and documentation of origin/passport data	0	0	19+2t	18	1	
3. Development and documentation of characterization data	0	0	6+2t	30+1t	1	
4. Development and use of molecular biology techniques and tools	0	0	1t+7+3t	26+1t	2	
5. Development and documentation of evaluation data	0	0	1+1t	32+3t	3	
6. GRIN	0	0	38+1t	1	0	
7. Distribution of germplasm	0	0	39	1	0	
8. Enhancement or prebreeding	0	0	1+1t	30+1t	7	
9. Breeding	0	0	8+4t	24+1t	3	
10. Regeneration and viability testing	0	0	16+3t	19+2t	0	
11. Active storage/preservation	0	0	25+1t	13+1t	0	
12. Backup storage/preservation	0	0	24+2t	13+1t	0	
13. Research on maintenance/preservation	0	0	10+6t	22	2	
14. Quarantine	0	0	1t+25	11+2t	1	
15. Other *(Please specify.)*						

15

44. In your opinion, if additional funds were made available to the NPGS for this crop or crop group, what priority should be given to each of the following areas for receiving the funds? *(Enter "1" for the greatest priority, "2" for the second greatest, etc., and "14" for the lowest priority. Use each number from 1 to 14 only once.)* (20-47)

1st Acquisition of germplasm

5th Development and documentation of origin/passport data

3rd Development and documentation of characterization data

7th Development and use of molecular biology tools and techniques

2nd Development and documentation of evaluation data

11th GRIN

10th Distribution of germplasm

4th Enhancement or prebreeding

9th Breeding

8th Regeneration and viability testing

6th Active storage/preservation

13th Backup storage or preservation

12th Research on maintenance/preservation

14th Quarantine

45. ***Comments.*** Please feel free to provide any additional comments you may have in the space below, including examples of the NPGS' strengths and weaknesses that you have highlighted in your answers. (48)

16

Crop Germplasm Committees and the Crops for Which They Are Responsible

CGC	Crop	Subcrop	Total samples
Alfalfa	Alfalfa	Alfalfa	3,003
		Wild relatives of alfalfa	4,515
			7,518
Apple	Apple	Apple	2,563
		Wild relatives of apple	2,246
			4,809
Barley	Barley	Barley	28,338
		Wild relatives of barley	2,074
			30,412
Carya	Chestnut	Chestnut	18
	Pecan	Pecan	563
		Wild relatives of pecan	318
			899
Citrus	Citrus	Grapefruit	59
		Lemon	69
		Lime	21
		Orange	236
		Orange, sour	45
		Pummelo	93
		Wild relatives of citrus	453
	Date Palm	Date Palm	98
	Kumquat	Kumquat	13
			1,087
Clover	Astragalus	Astragalus	852
	Clover	Clover, crimson	40
		Clover, red	1,284
		Clover, sweet	896
		Clover, white	822
		Wild relatives of clover	3,781
	Lespedeza	Lespedeza	152
	Trefoil	Trefoil	930
			8,757
Cool season food legume	Chickpea	Chickpea	4,434
		Wild relatives of chickpea	174
	Faba bean	Faba bean	538
		Wild relatives of faba bean	1,381
	Lentil	Lentil	2,724
		Wild relatives of lentil	149

(continued)

CGC	Crop	Subcrop	Total samples
	Lupins	Lupins	1,287
			10,687
Cotton	Cotton	Cotton	4,810
		Wild relatives of cotton	2,099
			6,909
Crucifer	Crucifers (Brassicas)	Broccoli	88
		Brussel sprouts	84
		Cabbage	1,032
		Canola	422
		Cauliflower	504
		Mustard	1,100
		Oil Brassica	544
		Rapeseed	655
		Rutabaga	24
		Turnip	139
		Wild relatives of crucifers	1,250
	Radish	Radish	748
		Wild relatives of radish	10
			6,600
Cucurbit	Cucumber	Cucumber	1,551
	Melon	Melons (honeydew, cantaloupe)	3,069
	Melon/cucumber	Wild relatives of melon/cucumbers	580
	Squash	Pumpkin	891
		Squash	831
		Zucchini squash	1,127
		Wild relatives of squash	531
	Watermelon	Watermelon	1,862
		Wild relatives of watermelon	34
			10,476
Grape	Grape	Grape	1,183
		Wild relatives of grapes	2,726
			3,909
Grass	Andropogon	Andropogon	1,100
	Bentgrass	Bentgrass	254
	Bermudagrass	Bermudagrass	524
	Bluegrass	Bluegrass	837
	Bothriochloa	Bothriochloa	672
	Bouteloua	Bouteloua	110

(continued)

CGC	Crop	Subcrop	Total samples
	Bromegrass	Bromegrass	1,071
	Buchloe	Buchloe	13
	Canarygrass	Canarygrass	759
	Cenchrus	Cenchrus	857
	Digitaria	Digitaria	652
	Elytrigia	Elytrigia	835
	Fescue	Fescue	2,050
	Gammagrass	Gammagrass	93
		Wild relatives of gammagrass	105
	Millet, Italian	Millet, Italian	759
		Wild relatives of Italian millet	248
	Millet, pearl	Millet, pearl	1,137
		Wild relatives of pearl millet	266
	Oatgrass	Oatgrass	228
	Orchardgrass	Orchardgrass	1,464
	Panicum	Millet	724
		Wild relatives of panicum	1,128
	Paspalum	Paspalum	1,501
	Ryegrass	Ryegrass	1,335
	Timothy	Timothy	626
	Wheatgrasses	Wheatgrasses	1,679
	Wild ryegrass	Wild ryegrass	555
	Zoysia	Zoysia	119
			21,701
Herbaceous Ornamental	Aster	Aster	10
	Begonia	Begonia	4
	Chrysanthemum	Chrysanthemum	23
	Day Lily	Day Lily	8
	Dianthus	Dianthus	90
	Euphorbs	Poinsettia	3
	Gentian	Gentian	1
	Geranium	Geranium	3
	Impatiens	Impatiens	18
	Liatris	Liatris	12
	Lily	Lily	28
	Petunia	Petunia	96
	Zinnia	Zinnia	80
			376
Juglans	Walnut	Walnut	266

(continued)

CGC	Crop	Subcrop	Total samples
		Walnut, black	35
		Wild relatives of walnut	162
			463
Leafy vegetable	Celery	Celery	86
		Wild relatives of celery	129
	Chicory	Chicory	250
	Lettuce	Lettuce	1,282
		Wild relatives of lettuce	222
	Parsnip	Parsnip	63
	Spinach	Spinach	379
			2,411
Maize	Corn	Corn	23,414
		Wild relatives of corn	251
			23,665
New Crops	Amaranth	Amaranth	1,818
		Wild relatives of amaranth	1,482
	Apios	Apios	3
	Calendula	Calendula	87
	Castor bean	Castor bean	1,032
	Crambe	Crambe	304
	Crotalaria	Crotalaria	260
	Cuphea	Cuphea	808
	Euphorbs	Wild relatives of euphorbia	87
	Evening primrose	Evening primrose	614
	Guar	Guar	1,303
	Guayule	Guayule	187
	Jojoba	Jojoba	155
	Kenaf	Kenaf	306
		Roselle	144
		Wild relatives of kenaf	350
	Lesquerella	Lesquerella	136
	Leucaena	Leucaena	573
	Lunaria	Lunaria	6
	Meadowfoam	Meadowfoam	56
	Mesquite	Mesquite	73
	Perilla	Perilla	22
	Quinoa	Quinoa	169
		Wild relatives of quinoa	52
	Safflower	Safflower	2,321

(continued)

CGC	Crop	Subcrop	Total samples
		Wild relatives of safflower	120
	Sesame	Sesame	1,221
		Wild relatives of sesame	9
	Stokes Aster	Stokes Aster	39
	Vernonia	Vernonia	267
	Yucca	Yucca	15
			14,019
Oat	Oat	Oat	10,269
		Wild relatives of oat	11,597
			21,866
Pea	Pea	Pea	4,245
		Wild relatives of pea	222
			4,467
Peanut	Peanut	Peanut	8,434
		Wild relatives of peanut	1,115
			9,549
Peppers	Peppers	Peppers	2,594
		Wild relatives of pepper	1,399
			3,993
Phaseolus	Bean	Bean	11,560
		Bean, lima	1,063
		Wild relatives of bean	1,192
			13,815
Potato	Potato	Potato	1,312
		Wild relatives of potato	5,778
			7,090
Prunus	Stone fruits	Almond	117
		Apricot	325
		Cherry	395
		Nectarine	9
		Peach	436
		Plum	237
		Wild relatives of stone fruits	1,224
			2,743
Pyrus	Pear	Pear	939
		Wild relatives of pear	1,368
			2,307
Rice	Rice	Rice	18,332
		Wild relatives of rice	241

(continued)

CGC	Crop	Subcrop	Total samples
			18,573
Root and Bulb	Carrot	Carrot	55
		Wild relatives of carrot	824
	Onion/Garlic	Garlic	122
		Leek	2
		Onion	1,081
		Wild relatives of onion/garlic	901
			2,985
Small Fruit	Blueberry	Blueberry	205
	Cranberry	Cranberry	121
	Blueberry/cranberry	Wild relatives of blueberry/cranberry	864
	Currant/Gooseberry	Currant/gooseberry	1,084
	Raspberry	Raspberry	336
		Wild relatives of raspberry	1,384
	Strawberry	Strawberry	504
		Wild relatives of strawberry	1,018
			5,516
Sorghum	Sorghum	Sorghum	39,931
		Wild relatives of sorghum	684
			40,615
Soybean	Soybean	Soybean	17,420
		Wild relatives of soybean	1,833
			19,253
Sugarbeet	Beet	Beet	1,567
		Wild relatives of beet	715
			2,282
Sugarcane	Sugarcane	Sugarcane	919
		Wild relatives of sugarcane	2,360
			3,279
Sunflower	Sunflower	Sunflower	2,673
		Wild relatives of sunflower	1,202
			3,875
Sweet Potato	Sweet potato	Sweet potato	720
		Wild relatives of sweet potato	452
			1,172
Tobacco	Tobacco	Tobacco	1,841
		Wild relatives of tobacco	305
			2,146

(continued)

CGC	Crop	Subcrop	Total samples
Tomato	Tomato	Tomato	8,123
		Wild relatives of tomato	1,983
			10,106
Tropical Fruit and Nut	Avocado	Avocado	474
		Wild relatives of avocado	14
	Banana	Banana	184
	Brazil nut	Brazil nut	1
	Breadfruit	Breadfruit	66
	Cashew	Cashew	1
	Cherimoya	Cherimoya	86
	Coffee	Coffee	1
	Guava	Guava	83
	Kiwi	Kiwi	12
		Wild relatives of kiwi	63
	Litchi nut	Litchi nut	135
	Macadamia	Macadamia	27
	Mango	Mango	295
	Papaya	Papaya	154
		Wild relatives of papaya	23
	Passion fruit	Passion fruit	36
	Pineapple	Pineapple	137
		Wild relatives of pineapple	25
	Rambutan	Rambutan	39
	Star fruit	Star fruit	70
			1,926
Vigna	Cowpea (blackeyed pea)	Cowpea (blackeyed pea)	7,783
		Adzuki bean	302
		Black gram	303
		Mung bean	3,919
		Wild relatives of Vigna	503
			12,810
Wheat	Rye	Rye	1,815
		Wild relatives of rye	106
	Triticale	Triticale	1,411
	Wheat	Wheat	34,618
		Wheat, durum	6,901
		Wild relatives of wheat	7,685
			52,536

(continued)

CGC	Crop	Subcrop	Total samples
Woody Landscape	Arborvitae	Arborvitae	9
	Barberry	Barberry	35
	Cedar	Cedar	3
	Cypress	Cypress	12
	Dogwood	Dogwood	170
	Elm	Elm	59
	Fir	Fir	22
	Hemlock	Hemlock	16
	Holly	Holly	130
	Juniper	Juniper	71
	Larch	Larch	5
	Lilac	Lilac	35
	Magnolia	Magnolia	44
	Maple	Maple	225
	Oak	Oak	57
	Pine	Pine	81
	Privet	Privet	37
	Redbud	Redbud	66
	Rhododendron	Rhododendron	100
	Rose	Rose	150
	Silverbell	Silverbell	106
	Sourwood	Sourwood	6
	Spiraea	Spiraea	50
	Spruce	Spruce	20
	Viburnum	Viburnum	105
	Yew	Yew	20
			1,634
All CGCs			**399,236**

Notes: The information in this appendix was provided by NPGS officials from the GRIN database as of February 28, 1997. In addition to the 399,236 germplasm samples shown above, NPGS maintains more than 35,000 other samples that are not listed here because they have no CGCs providing advice and guidance on them.

Comments From the U.S. Department of Agriculture

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

United States Department of Agriculture | Agricultural Research Service | Office of the Administrator | Washington, DC 20250

September 17, 1997

Mr. Robert A. Robinson
Director, Food and Agriculture Issues
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Robinson:

This is in response to your letter of September 10, 1997, which had enclosed the draft General Accounting Office (GAO) report entitled "U.S. Department of Agriculture: Information on the Condition of the National Plant Germplasm System" (GAO/RCED-97-237, Code 150713).

As requested, I have reviewed the report and am providing the following comments.

See comment 1.

The USDA appreciates the extraordinary effort and cooperation of the GAO in conducting its extensive survey and analysis of the status of the U.S. National Plant Germplasm System (NPGS). We take note that, at the conclusion, the GAO made no specific recommendations. The GAO apparently recognizes that the complexity of the large diverse NPGS with its diverse user community with a multiplicity of different interests, precludes a simple analysis and development of uniform remedies. The individual chapters of the GAO study represent categorized case examples from the survey that collectively document the further progress which is needed.

We have been pleased to receive numerous comments, from both national and international recipients of germplasm, communicating their satisfaction with the rapidity and responsiveness with which they have received germplasm and information ordered from the NPGS. The USDA believes it has made large strides since the earlier reviews conducted by the GAO and National Research Council (NRC), and would have liked some recognition in the current study reflecting the very positive advancements made in acquisition, quarantine, documentation, preservation, characterization, and evaluation (Attachment 1). Considerable person-year efforts have been devoted by the NPGS to improving these capabilities but the successes are dwarfed by the volume of increased responsibility the NPGS has assumed by accepting much new germplasm and by its dedication to improving the management of crops having reproductive systems requiring intensive labor efforts. The backlogs in regenerating germplasm are not in the "easy to regenerate" crops, but rather in crops that require controlled pollination and large population sizes.

The USDA notes that the survey documents that the priorities recommended by the Crop Germplasm Committees (CGCs) vary considerably across crops. This phenomenon underscores that the curators are the key connecting links between the users, CGCs, and NPGS management.

Mr. Robert A. Robinson 2

They are responsible for managing the acquired germplasm, by characterizing, documenting, preserving and distributing it. They interact extensively with the CGCs and are acutely aware of the CGCs' multiple and potentially conflicting priorities. The curators will continue to serve as the most important source for information and guidance needed to balance the priorities of the diverse interests of the scientific community.

See comment 2.

Chapters 2, 3 and 4 vividly demonstrate that the germplasm user community and NPGS germplasm managers have sometimes developed divergent sets of priorities, according to the divergent interests of each party. This divergence does not indicate that one party is misguided, and the other not, but rather that their perceptions of priority activities correspond closely to their primary programmatic mandates. The primary missions of the user community, as mandated by public and private sector administrators and by funding agencies, are to conduct basic research programs aggressively, and improve crop productivity as rapidly and effectively as possible. Thus, it was predictable that in the present study the user community would place high priority on acquiring more potentially valuable germplasm, on identifying traits of clear agronomic or horticultural utility in the thousands of NPGS accessions, and on communicating this vital information rapidly via the Germplasm Resources Information Networks (GRIN) database. The preceding germplasm management activities are instrumental for furthering progress toward attaining their mandated missions.

In contrast, the primary missions of the NPGS are 1) to conserve effectively and efficiently as much unique genetic variability in crop genepools and key descriptive information as possible according to internationally-recognized quality standards of health, purity, and genetic stability; and 2) to distribute that germplasm and information to requestors as effectively and efficiently as possible. Germplasm evaluation, characterization, and indiscriminant acquisition rank as lower priority activities for NPGS programs. The preceding NPGS priorities are widely accepted; indeed, previous reports by the GAO, NRC, and some CGCs recommended that the NPGS address as a matter of priority perceived deficiencies in the quality of germplasm storage, maintenance, and availability, and in database content and database management.

See comment 3.

Faced with these past recommendations and conscious of accepted NPGS and international standards for germplasm management, it is not surprising that the present report documents NPGS germplasm managers' grave concerns regarding the rate of progress with improving databases further, and with regenerating, viability-testing, and backing-up accessions in long-term storage. In sharp contrast, throughout Chapters 3 and 4 of the present report, the CGCs repeatedly note that the NPGS's management of data (passport, characterization, and evaluation), and the GRIN system in particular, have improved tangibly during the last 6 years. Furthermore, the majority of the CGCs clearly indicate that the pace at which germplasm is being regenerated, tested for viability, and backed-up is acceptable to them. In their view, more resources should be devoted to acquiring, characterizing, and evaluating germplasm.

See comment 4.

Mr. Robert A. Robinson 3

Thus, the NPGS and, in particular, its curatorial staff, clearly faces a substantial programmatic and managerial dilemma. Without substantial additional resources (see comments in other sections of this response), two somewhat conflicting sets of managerial priorities cannot be addressed simultaneously with acceptable rates of progress nor quality of effort. Unless the NPGS's funding base is augmented, an over-extended NPGS staff will for the foreseeable future face the onerous task of juggling multiple, divergent priorities by making incremental progress with addressing an exceptionally broad range of user demands. Rather than pleasing its large user community with optimal service and responsiveness, at best it would not strongly displease that community, while deploying its shrinking base of resources to meet both internationally-recognized standards for germplasm preservation, and the demands of its users.

The NPGS faces several dilemmas caused by declining budgets. The priorities must be adjusted and balanced to utilize the personnel and the available funds in the most efficient manner. Although the GAO summary does not directly state the obvious, the common thread which unifies all of the chapters is the impact of inadequate resources to discharge responsibilities mandated by the Congress (P.L. 101-624). These responsibilities have been borne primarily by the ARS, guided by the public and private sector scientists of the CGCs and the scientific community as a whole. The USDA requests for additional funding to address the challenges highlighted by GAO have not been granted in general despite public acknowledgment in both popular and scientific press, that the deficiencies in preservation of critical germplasm places U.S. food security at risk for the future. In addition, the U.S. will be further disadvantaged in competitiveness as new technologies and information come from genomic studies when it is faced with a diminishing range and quality of genetic resources to which those new methods could be applied.

ARS has been particularly supportive of budget increases for NPGS activities. ARS has redirected some funding to NPGS activities but that has been quite insufficient. Further, because funding has not been increased, ARS units have reduced staffing levels by not filling key vacancies and reduced research and other activities which USDA and CGCs believe are important to NPGS users. ARS appreciates greatly the efforts of the State agricultural experiment station directors to maintain constant budgets and even increase funding for the regional introduction stations as well as their strong support for many NPGS activities on their university campuses. The seed industry's help with regenerating and evaluating germplasm and advising regarding needs of agribusiness is greatly appreciated.

Acquisition is a case in point regarding use of resources. Plant explorations, although costly, are not nearly as costly as the thousands of new accessions acquired by exchange. Those accessions may immediately impose costs of regeneration for distribution, viability testing, and data acquisition, validation and entry. Germplasm characterization and evaluation tests must be conducted so that new accessions are documented to the same degree as other accessions. Acquiring those data relatively rapidly, when evaluations must be conducted under varying test conditions and over many years, is a daunting challenge which additional resources alone cannot immediately solve. USDA and even some CGCs noted the lack of scientists available to evaluate germplasm because the public sector has greatly reduced its plant breeding activities.

Another aspect of access to germplasm in the future involves the potential impact of the Convention on Biological Diversity on the NPGS. Although in principle, the Convention's devotion to conservation, sustainable use, and benefit sharing would seem totally compatible with NPGS objectives, many countries who have ratified the Convention have passed national legislation impeding access to germplasm. The NPGS has refused when exchanging germplasm to agree to conditions impeding unrestricted distribution. The NPGS has received germplasm freely in the past and consequently distributes its germplasm freely--without regard to a balance of germplasm exchange list. Unfortunately many developing countries' unrealistic expectations of high monetary returns from selling access to germplasm for agriculture have placed crop breeders in those countries in a difficult position. Those breeders, the key to improving food security for their countries, are losing their ability to exchange germplasm freely as restrictions are imposed.

See comment 5.

The U.S. is greatly concerned with world food security issues and is negotiating in international fora (particularly at the Commission on Genetic Resources for Food and Agriculture of the Food and Agriculture Organization of the United Nations) to maintain an international regime of unrestricted access to plant genetic resources, particularly germplasm accessions of key staple food and other crops in national and especially in international collections. Although the U.S. is not home to major food crops, as noted in this report, its collections are an important germplasm source for global food production. The U.S. will continue to work closely with other nations to help preserve germplasm and to convince all people that the unrestricted flow of agricultural genetic resources is in the mutual interest of all nations for current and future world food security. When access to other collections is assured through international treaty, the need to accumulate more germplasm accessions is reduced and the burden of managing germplasm is spread more uniformly internationally. Until then, the NPGS will continue to acquire and to bear the heavy cost of maintaining the extensive U.S. collections. It will attempt to work with other nations having more vulnerable collections to secure germplasm for future generations. It will work with like-minded nations to secure beneficial bilateral or multilateral exchange agreements. The USDA will continue to request and reallocate resources to support its own collections and will work with other Federal and State agencies and organizations and the private sector to assure that the NPGS is managed optimally.

The USDA's NPGS appreciates the support and cooperation of other Federal agencies in USDA, U.S. Agency for International Development, National Science Foundation, National Institutes of Health, Department of Interior, and Department of State for its goals of maintaining a strong genetic base for U.S. and global agriculture. GAO's efforts to help identify and resolve issues

Mr. Robert A. Robinson 5

vital to the welfare of the American public through its reports to the Congress will also help us to achieve this goal.

Sincerely,

EDWARD B. KNIPLING
Acting Administrator

Enclosure

Attachment 1

NPGS Progress 1990-1996 in Addressing Priority Managerial Goals

The following narrative summarizes some of the highlights of progress made by the NPGS in addressing some of its priority managerial goals. These priorities were established by NPGS germplasm management staff according to recommendations from the previous GAO study, various studies by the National Research Council, and extensive consultation with Crop Germplasm Committees and other user groups.

In general, the current GAO study recognizes that germplasm maintenance, regeneration, distribution, and data management efforts represent strengths for the NPGS. Due to the nature of the GAO survey instrument, the magnitude of the effort involved with establishing these programmatic strengths may have not been clearly communicated, so we offer the following concrete examples of NPGS's achievements.

Since 1990, the holding capacity of the National Seed Storage Laboratory (NSSL), NPGS's long-term germplasm maintenance site, has been more than doubled. Nearly two-thirds of the entire NPGS collection (440,000 + accessions) is now backed up at NSSL, and some individual crop collections (e.g., those at Aberdeen, Urbana) are nearly completely backed up. Many clonal collections (e.g., hickory, bamboo, mango, avocado, and sweet potato) are also backed up in field plantings. Cryopreservation programs were established for apple clones (NSSL, Geneva) and pears (Corvallis, NSSL), whereas in vitro protocols for crops such as breadfruit, mints, macadamia relatives, and pineapples were implemented.

Germplasm storage facilities at all of the major active sites for managing seed-propagated germplasm have been substantially improved. Walk-in or upright -20C freezers have been installed in Aberdeen, Griffin, Ames, Geneva, Pullman, College Station (for Carya), and Urbana, where cold room space for the maize genetic stock collection has more than doubled. These -20C freezers provide optimal storage for original seed and seed that deteriorates rapidly. Storage conditions for seed lots maintained for distribution have been enhanced at most active sites by the installation of silica gel dehumidifiers, which will maintain seeds at an optimal internal water content.

The health of germplasm maintained by the NPGS has also improved tangibly. Molecular plant pathology screening protocols for seedborne or cutting-borne diseases have been established at Ames, Riverside, Hilo, Griffin, and other sites. Virus detection and elimination programs have been especially vigorous for legumes at Pullman and Griffin, and tropical fruits and nuts at Hilo. Griffin has been certified as a post-harvest quarantine site for peanuts, and Geneva has been so certified for grapes. The NPGS also is managing some beneficial microbes with a program for identifying and maintaining grass endophytes established at Pullman.

Much of the NPGS's budget during 1990-96 was devoted to regenerating germplasm from seeds. It is difficult to summarize the exact numbers of accessions regenerated, but the total probably comprises at least 25% of the entire NPGS's collection (or 100,000 accessions). Much of this

2

progress occurred at the regional plant introduction stations and the National Small Grains Collection (Aberdeen). Particularly notable efforts include soybeans, sorghum, maize, and small grains collections. There were also important qualitative improvements in regeneration programs, such as more efficient pollination systems for crops established at Ames and Pullman. Implementation of insect cages at Urbana greatly improved quality of 16,000 soybean accessions regenerated. Several major controlled pollination programs (Geneva, Griffin, alfalfa at Prosser, sugar beets at Pullman) were established de novo. Propagation success was greatly improved for a variety of tropical fruit crops at Hilo.

The NPGS's data management effort was commended in the current GAO report, and rightfully so. Data management efficiency has been significantly improved by the implementation of bar coding for germplasm packets or field plantings at NSSL, Ames, Geneva, Aberdeen, and other sites. Outstanding progress was achieved in improving the Germplasm Resources Information Network (GRIN) database, for which a major upgrade occurred 4 years ago. The period of 1990-1996 saw the development of the Internet, and particularly the World Wide Web, as a revolutionary tool for worldwide communication. The NPGS responded by upgrading the main computer for GRIN, and literally hundreds of personal computers at NPGS active sites. Many active sites upgraded their telecommunications capabilities by installing new high speed datalinks, and local area networks. The GRIN website was established, and receives more than 3,000 queries/month. Site specific web pages that were established at Urbana, Ames, Corvallis, and most of the other management sites further facilitate communications with the user community. Some of our curators are actively developing genome databases, e.g., the genome database for rose family (apples, pears, etc.) plants initiated at Geneva in conjunction with Cornell University scientists.

One of the most important measures of the quality and effectiveness of a germplasm system is the number of germplasm accessions distributed, and the relative demand for those accessions. As a result of the preceding and other activities, the NPGS distributed an enormous quantity of germplasm during 1990-1996. On an average, the NPGS distributes about 25% of its entire collection (more than 100,000 accessions) per year, and that figure is increasing. For example, the number of maize genetic stock accessions distributed doubled. More than 90% of the soybean collection at Urbana has been requested at least once during the last 3 years, and nearly all of the available collection at Ames has been requested at least once during the last 5 years. These distributions (e.g., seeds and graft wood of pecan) are increasingly international in scope.

The NPGS also made tangible progress with those activities (acquisition, evaluation, characterization) which the GAO survey suggests should be reemphasized whenever additional funding is available. The NPGS collection grew by more than 15% during 1990-1996, and some of the germplasm acquisitions are particularly notable, in that they filled important gaps in genetic diversity, or rescued endangered, high-value accessions. For example, 4,500 soybean accessions, most from China--the center of origin for soybean--were acquired by the soybean collection at Urbana. The maize genetic stock collection in Urbana has more than doubled in size by incorporating stocks endangered by the death or retirement of maize geneticists. The clonal site in Corvallis nearly doubled its holdings. Important pecan accessions for host-plant resistance were acquired, and major field collections of pecan were made in Mexico, China, and Vietnam. Important collections of tropical fruits (lychee, rambutan, mango) were secured in Asia. More than 75 plant exploration expeditions were supported by the NPGS. An extensive, coordinated series of seven potato collecting expeditions to Latin America conducted by scientists at Sturgeon Bay and Madison, Wisconsin exemplifies the relatively aggressive exchange effort of the NPGS for certain crops.

Furthermore, substantial progress with characterizing germplasm accessions has occurred. Thousands of accessions' passport data have been upgraded at sites such as Aberdeen, Ames, and Griffin to include latitude and longitude, a process that has required thousands of human-hours. Descriptor lists were newly established for crucifers, Cuphea, 75% of the tropical fruit and nut genera at Hilo, and for ornamental germplasm. Geographical positioning systems are now a part of every NPGS-sponsored plant exploration. A Geographic Information System (GIS) prototype for managing germplasm information was developed at Pullman. Programs for capturing and managing digital images of germplasm were established at the NSSL, Pullman, College Station, Aberdeen, and Ames. Preliminary core subsets have been established for many NPGS crops (e.g., cool season legumes, sorghum, citrus, mungbean, peanuts, eggplant, okra) and, in the process of doing so, much has been learned regarding the apportionment of genetic diversity in crops and their wild relatives.

During the last decade, molecular tools have revolutionized biology; during the last 6 years, these tools were incorporated into the characterization programs of many NPGS active sites. Molecular marker analysis programs were established de novo at Ames, Riverside, Griffin, Geneva, College Station (Carya), Sturgeon Bay, Urbana, and Pullman; a cooperative program between the Hilo site and the University of Hawaii has already molecularly characterized 80% of that site's accessions. DNA markers have been developed at Griffin for sorghum, Paspalum, peanut, watermelon, sweet potato, Brassica, and maize; at Geneva for apples, grapes, and cherries; and at Ames for maize, sunflowers, and amaranths.

Despite a paucity of funds available for that purpose, germplasm was evaluated at NPGS sites, or, more commonly, much evaluation data was secured from other scientists and entered into GRIN. For example, the evaluation data available for small grains germplasm on GRIN has nearly doubled to 1.7 million records during the last 6 years, thanks to efforts at the Aberdeen site. More than 16,000 accessions of soybeans were evaluated preliminarily at Urbana. More than 7,800 accessions of sorghum were evaluated at Mayaguez, yielding more than 300,000 data points. Genotype/water use efficiency was evaluated for crops at Pullman. Extensive evaluation programs for maize host-plant resistance to insects, sunflower and sugarbeet host-plant resistance, adaptation of woody ornamentals, etc., were coordinated by NPGS personnel at Ames.

The progress reported above could not have been achieved without major improvements in the NPGS's infrastructure. The amount of land available for germplasm regeneration was increased tangibly, e.g., field space available at Urbana for maize doubled, and a new irrigation system was purchased; eight acres of land at Griffin and 50 acres at Byron, Georgia were secured for the Griffin plant introduction station; and, at Geneva 35 acres were leased for regeneration. At Corvallis, 40 acres of land were purchased and supplied with an irrigation system. An entirely new regeneration site was developed de novo at Parlier, California. This involved extensive negotiations and infrastructure development from the ground up to establish a site to supplement the rest of the NPGS. Regeneration was also facilitated by greenhouses built at Ames, Griffin, Pullman, Geneva, College Station, and Riverside, and screen houses at Pullman and Geneva. Office space was built or renovated at Griffin, Geneva, Riverside, and Parlier. Farm buildings, seed processing facilities, and tissue culture rooms were renovated or established at a variety of sites. A post-entry quarantine facility for grapes was newly established at Geneva. Maintenance efficiency for soybeans was increased with consolidation of Urbana and Stoneville collections. A large, new 1,700 sq. ft. molecular lab was established at Griffin, and other smaller molecular labs were renovated or assembled elsewhere.

Efficiencies in management have extended to cooperation in international and bilateral efforts. Collaboration with genebanks of many of the international agricultural research centers, such as the International Center for Maize and Wheat Improvement, the International Rice Research Institute, the International Crops Research Institute for the Semi-Arid Tropics, the International Center for Tropical Agriculture and the International Potato Center, have led to increasing security back up for the NPGS and those centers. In bilateral cooperation, the NPGS has worked closely with many countries for improving linkages and sharing of genetic resources. From 1990-1996, the NPGS exchanged germplasm with 151 countries demonstrating that all countries truly benefit from an unrestricted exchange policy.

The following are GAO's comments on USDA's September 17, 1997, letter.

GAO's Comments

1. We agree that NPGS has made improvements in a number of areas over the past 6 years, as USDA discusses in the attachment to its letter. However, the purpose of our review was to obtain the views of the CGCs—crop experts who advise NPGS—on the sufficiency of NPGS' principal activities: acquisition, development and documentation of information, and preservation of germplasm. Thus, the report focuses on the current status of NPGS' activities and not on improvements made to the system. However, chapter 1 discusses actions taken during the 1990s to address identified shortcomings—in particular, the expansion of NSSL's long-term storage capacity, the increased use of –18 degree Celsius storage by NPGS sites, and improvements made to the GRIN database. In addition, other chapters discuss areas where most CGCs reported that aspects of NPGS collections or activities were sufficient. Therefore, given the purpose of our review and the language already incorporated into the report, we did not add information on other improvements.

2. While our report cites curators and CGCs as having different views on the sufficiency of some NPGS activities—e.g., preservation and passport information—they do not, for the most part, have different views on NPGS' top priorities. According to survey responses, both curators and CGCs, on average, viewed acquisition as their top priority if additional funding becomes available. Development and documentation of characterization information is also ranked highly by curators and CGCs (they ranked it second and third, respectively), as is development and documentation of evaluation information, which is ranked fifth by curators and second by CGCs. On the other hand, there were greater differences in the CGCs' and curators' ranking of regeneration and viability testing, with curators ranking it third and CGCs, eighth. (See app. II, question 44.)

3. We wish to clarify USDA's interpretation of our survey results. While chapter 3 notes that almost all CGCs reported that the management of GRIN has improved since about 1990 and three-quarters said that the management of passport data had improved, the survey results are less clear-cut with regard to the management of characterization and evaluation data. Specifically, over half (22) the CGCs said that the management of characterization data has improved, 17 said that there is no change, and 1 CGC said that it has worsened. For the management of evaluation data, just under half (19) said that the management of

evaluation data has improved, half (20) said that there is no change, and 1 said that it has worsened. (See question 42, app. II.)

In chapter 4, we state that relatively few CGCs reported that regeneration, viability testing, and backup storage are insufficient for their crop collections. However, we also report that almost three-quarters of the CGCs stated that the lack of staff for regeneration and viability testing has hindered preservation of their crop collections. In response to question 43 on the amount of funding NPGS provides for these activities, given current resources, 19 CGCs reported that for regeneration and viability testing it is about the right amount and 21 reported that it is probably too little. For backup storage/preservation, 26 CGCs reported that it is probably the right amount and 14 that it is probably too little. (See question 43, app. II.)

4. We appreciate the challenges NPGS faces in having to juggle multiple priorities and manage continually increasing collections in the face of declining resources. We hope that our report will provide useful information to congressional and other decisonmakers in future deliberations on the role of NPGS and the resources available to NPGS for carrying out its role.

5. We support USDA's efforts to optimize the management of NPGS to make most effective use of its limited resources.

Major Contributors to This Report

Resources, Community, and Economic Development Division, Washington, D.C.

Jerilynn B. Hoy, Assistant Director
Beverly A. Peterson, Evaluator-in-Charge
Sonja J. Bensen
Nancy S. Bowser
Carolyn M. Boyce
Carol Herrnstadt Shulman

Ordering Information

The first copy of each GAO report and testimony is free. Additional copies are $2 each. Orders should be sent to the following address, accompanied by a check or money order made out to the Superintendent of Documents, when necessary. VISA and MasterCard credit cards are accepted, also. Orders for 100 or more copies to be mailed to a single address are discounted 25 percent.

Orders by mail:

U.S. General Accounting Office
P.O. Box 37050
Washington, DC 20013

or visit:

Room 1100
700 4th St. NW (corner of 4th and G Sts. NW)
U.S. General Accounting Office
Washington, DC

Orders may also be placed by calling (202) 512-6000
or by using fax number (202) 512-6061, or TDD (202) 512-2537.

Each day, GAO issues a list of newly available reports and testimony. To receive facsimile copies of the daily list or any list from the past 30 days, please call (202) 512-6000 using a touchtone phone. A recorded menu will provide information on how to obtain these lists.

For information on how to access GAO reports on the INTERNET, send an e-mail message with "info" in the body to:

info@www.gao.gov

or visit GAO's World Wide Web Home Page at:

http://www.gao.gov