1

History and Operation of the National Plant Germplasm System

George A. White
Plant Introduction Officer, Germplasm Services Laboratory
Plant Sciences Institute
U.S. Department of Agriculture, Agricultural Research Service
Beltsville, Maryland 20705

Henry L. Shands
National Program Leader for Germplasm
U.S. Department of Agriculture, Agricultural Research Service
Beltsville, Maryland 20705

Gilbert R. Lovell
Coordinator
Regional Plant Introduction Station
U.S. Department of Agriculture, Agricultural Research Service
Griffin, Georgia 30223-1797

I. INTRODUCTION

The National Plant Germplasm system (NPGS) has evolved over a considerably shorter period of time than the plants curated within it. However, just as with plant evolution the successful components have survived. Plant introduction began when the settlers to America brought useful plants from all over the world to fill their needs in a new land almost devoid of native food and fiber crop species. Early farm and plantation owners sought the aid of the international diplomatic corps to bring useful plants from foreign lands to enrich their farms and the new nation's plant industry. The Department of Agriculture's founding in 1862 increased the interest in plants, and in 1898 the Section of Seed and Plant Introduction was founded to begin plant exploration and the formal plant introduction program.

Plant introductions became the basis of crop improvement, and plant breeders and other researchers utilized them heavily to introduce new traits for stress and pest resistance and improved yield performance into new cultivars. Breeders, whether federal, state or private, became the curators for these introductions and maintained them as best they could for the value they saw in them. As late as the 1940s, only a few institutions had the facilities to provide minimal conditions for preserving seeds. Few scientists at that time sought the yet unknown requirements for refrigerated and dehumidified conditions now recognized as crucial for the storage of crop seeds. A study conducted in 1943 by the National

Research Council identified the need for more organized regional activities relating to plant conservation, and through the legislation of the 1946 Research and Marketing Act, the National Potato Introduction Station and the Regional Plant Introduction Stations were established. Private seed collections of breeders, geneticists, cytogeneticists and others who had assembled introductions, unique germplasm and chromosomal marker stocks became recognized as important to preserve. Funding, however, was insufficient to assimilate these local collections into larger management units.

The 1970 southern corn blight epidemic incited by *Helminthosporium maydis* caused the agricultural community to look at its responsibilities in increasing crop genetic diversity. The 1972 National Academy of Science report on genetic vulnerability of the nation's crops and internal reviews suggested that a National Board for Plant Genetic Resources (NPGRB) be established to advise the Secretary of Agriculture on plant germplasm issues and to recommend appropriate policies. In 1976, the National Plant Germplasm Committee (NPGC) consisting of federal, state and industry representatives evolved from the previous New Crops Coordinating Committee to advise the NPGS.

Today the NPGS presents itself as a user-oriented system with the goal of acquiring, preserving, and distributing plant germplasm. It consists of operational units, advisory committees, and administrative and financial support organizations. Operational activities consist of plant exploration, introduction, quarantine, seed and clonal working collections and repositories, base collection and repository, and germplasm related research activities including evaluation and enhancement.

II. HISTORY OF NPGS

The United States is a "have not" country in respect to native crop species. This is a major factor contributing to its present world leadership in agricultural production. Early colonists necessarily brought their favorite seeds with them. The American Indians had, at the time of colonization, small fruits, some nuts, sunflowers (including artichoke), and *Apios* groundnut as well as introduced crops of maize, beans, tobacco, cotton, and squash. As Indians migrated northward from Mexico and points further south, they brought seeds with them. Thus most crops grown here still are introduced species (Fig. 1.1–1.3). Several writers have addressed the history of early plant introduction activities and mentioned high level governmental officials and offices that strongly supported such activities (Hyland 1976; Wilkes 1985; Parliman and White 1985). Our treatment of events begins in 1898, and except for some brief backtracking, traces the development and operation of what is now called the National Plant Germplasm System of the United States.

Fig. 1.1. Centers of origin for some agronomic crops illustrate the dearth of crop species that originated in the western hemisphere north of Mexico.

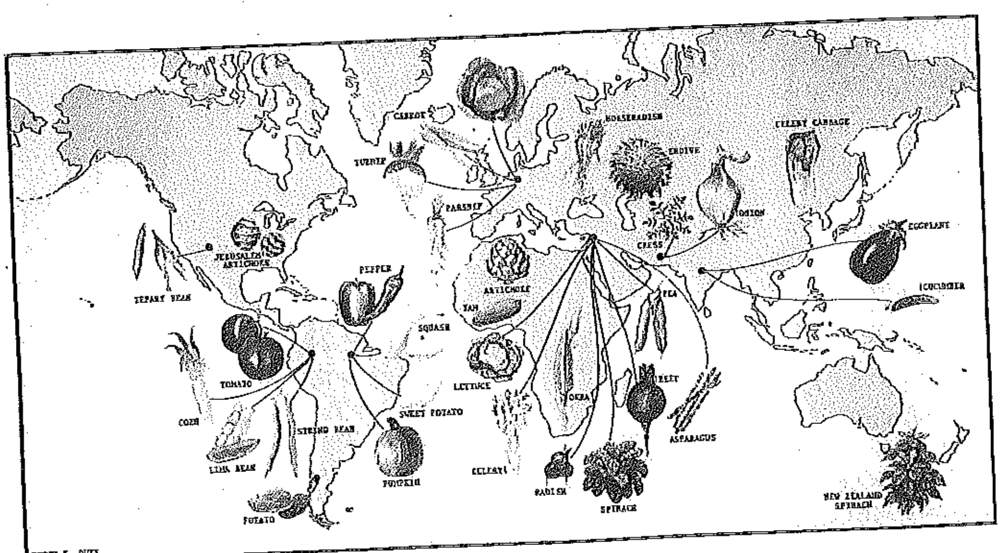


Fig. 1.2. Centers of origin for some vegetable crops illustrate the dearth of crop species that originated in the western hemisphere north of Mexico.

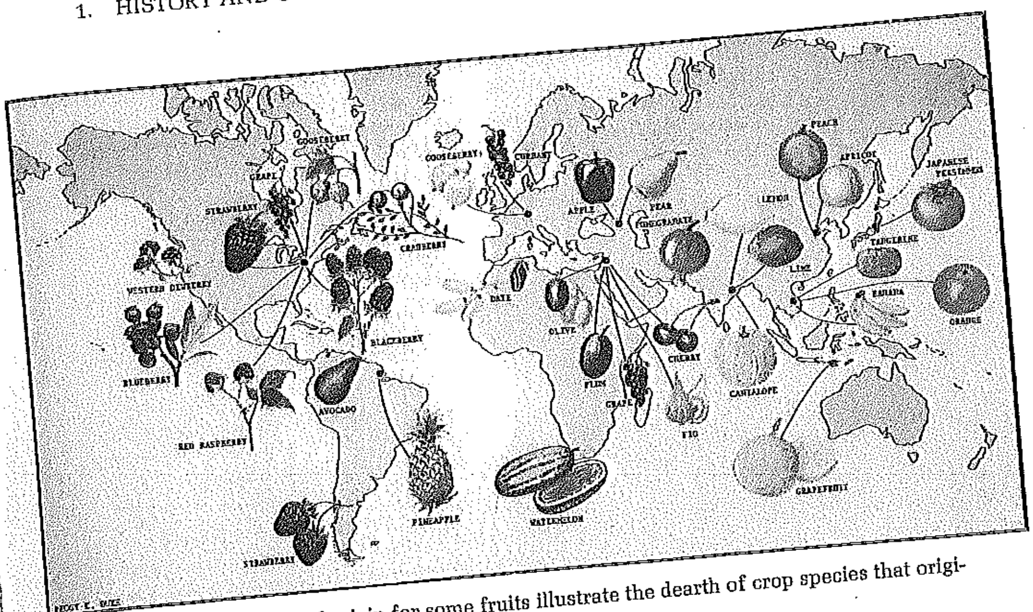


Fig. 1.3. Centers of origin for some fruits illustrate the dearth of crop species that originated in the western hemisphere north of Mexico.

A. Plant Introduction and Exploration

In 1898, the still fledgling Department of Agriculture (USDA) established the Section of Seed and Plant Introduction. Hence, this made the Plant Introduction Office (PIO) the oldest formal entity of the present-day system. Hyland (1976) traced the names of the USDA units responsible for coordinating plant introduction and exploration from 1898 to 1976. The following organizations need to be added to Hyland's list: the Plant Taxonomy & Exploration Laboratory, the Germplasm Introduction & Evaluation Laboratory, and currently the Germplasm Services Laboratory. Plant Introduction (PI) number assignments began in 1898, and USDA Plant Inventories which contain the records of these assignments have been published continuously since then. The first documented PI was a cabbage from Russia (Table 1.1). The emphasis over the next three or more decades centered on the introduction and distribution of new and useful seeds to farmers and commercial growers.

In 1898, the Federal Plant Introduction Garden, now known as the Subtropical Horticulture Research Station, was established in Miami,

Table 1.1. Plant introductions through the years.

PI number	Crop	Year of introduction	Country of origin
1	*Brassica oleracea* var. *capitata*	1898	USSR
100	*Cucumis melo*	1898	USSR
1,000	*Triticum aestivum*	1898	USSR
10,000	*Linum usitatissimum*	1903	USSR
100,000	*Primula chungensis*	1932	China
200,000	*Guizotia abyssinica*	1952	Ethiopia
300,000	*Hibiscus vitifolius* subsp. *vulgaris*	1964	Rep. of S. Africa
400,000	*Oryza sativa*	1975	Philippines
500,000[1]	*Triticum aestivum*	1985 (Dec. 11)	United States
514,275	*Sorghum bicolor*	1987 (Dec. 31)	Benin

[1]PI 500,000 (Purplestraw wheat) was grown in the Southeastern and Southern United States for more than 125 years. It appeared in the parentage of several other cultivars for the same area. "Celebration PI 500,000" commemorated 87 years of highly successful plant introduction activities.

Florida. Other plant introduction gardens or stations followed: Chico, California in 1904; Savannah, Georgia and Glenn Dale, Maryland in 1919. As recipients of a wide range of plant species, these Plant Introduction Stations became important sources of seeds, plants, cuttings and associated information for use by growers. The Chico Station was closed in 1973; the Savannah station in 1981. The Miami Station is one of several clonal repositories. Glenn Dale is primarily a quarantine facility used for virus-indexing of introduced fruit, potato, and sweet potato germplasm and, in 1987, became a repository for the woody ornamental collection under development at the National Arboretum.

The period of 1898–1930 was one of extremely active plant exploration. Considerable activity occurred during 1850 to 1898. Significant introductions of navel oranges, flax, olive, persimmon, sorghum, wheats, and other cereals occurred after the creation of USDA in 1862 up to 1898 (Univ. of Georgia 1971). Considering the difficulties of sea and land travel, the successes of these early explorations are remarkable.

The accomplishments of Frank N. Meyer are documented (Cunningham 1984) as are the achievements of David Fairchild who headed the Section of Foreign Plant Introduction. There were several other individuals who introduced materials of enormous value to crop production (Fig. 1.4–1.5). However, because of the lack of storage facilities, the high cost of frequent regenerations, and the use in breeding research, most of the early introduced accessions have been lost.

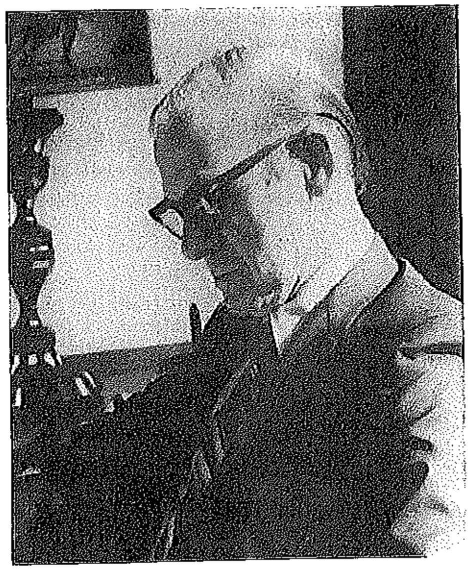


Fig. 1.4. Howard L. Hyland in his efficient and quiet manner effectively served as the USDA-ARS Plant Introduction Officer for the period of 1948 through April 1977. During this period, he had the responsibility for the documentation and assignment of approx. 244,152 PI numbers and coordinated the exchange with many countries of several hundred thousand seed and plant samples. Photo courtesy of H. L. Hyland (1977).

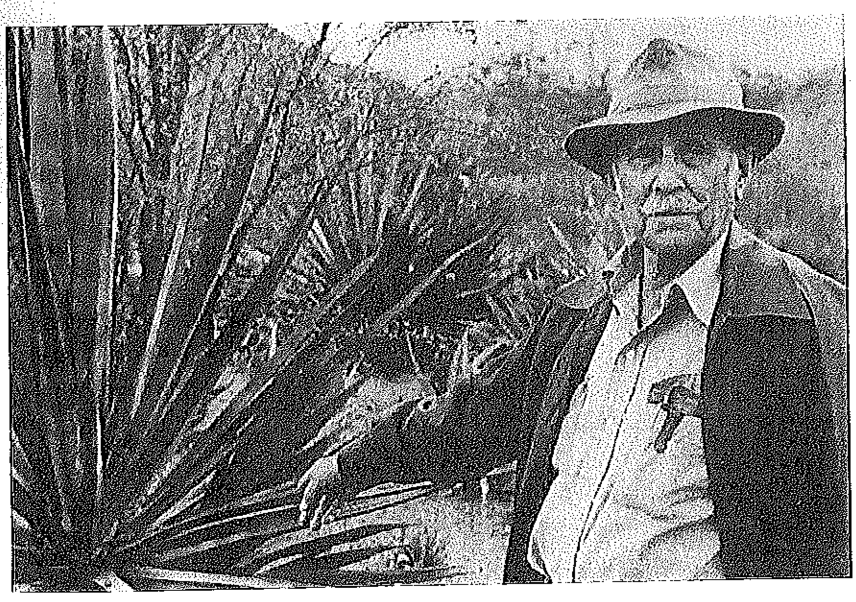


Fig. 1.5. Dr. Howard Scott Gentry observes agave plants at the Desert Botanical Garden, Phoenix. Gentry, botanist and plant explorer for USDA-ARS from 1950–April 1971, collected a wide diversity of plant germplasm. His collections included beans and agave from Mexico, peas and cereals from Ethiopia, new crops from South Africa and the United States, and forage species from Europe, Yugoslavia, and the Balkans. After retirement, he continued exploring especially in Mexico for species of interest to the Desert Botanic Garden (Cunningham, 1987). Photo courtesy H. S. Gentry.

B. Quarantine

During early American history, many pests such as weeds, insects, and diseases made their way here through such routes as seedlots, straw, hay, other feedstuffs, food, clothing, wool, equipment, and ship ballast. The first U.S. Plant Quarantine Act was enacted in 1912 (Waterworth and White 1982). The advent of the white pine blister rust, the chestnut blight fungus, the citrus canker bacterium (subsequently eliminated) and other pests provided the impetus for the quarantine law. The Organic Act of 1944 provided for pest management strategies, control programs against domestic and exotic pests, and issuance of phytosanitary certificates relative to the requirements of foreign countries. The final major act, the Federal Plant Pest Act of 1957, authorized emergency measures to prevent the introduction or interstate movement of pests not covered under the 1912 act. It also broadened the definition of pests to include all insects, mites, slugs, nematodes, bacteria, fungi, parasitic plants, viruses, and other organisms that can damage plants or processed plant products. This act allows the introduction of exotic pests for scientific study.

With formalization of quarantine and plant introduction activities within USDA, the agencies involved have worked closely together to guard against the introduction of serious crop pests both to the U.S. and to other countries. The Washington Inspection Station was housed in the old Auditors Building, 14th and Independence Ave., Washington, D.C. and other nearby locations from 1930 to 1977. Since then, Building 320 on the east side of the Beltsville Agricultural Research Center has been the home of the Plant Germplasm Quarantine Center, a facility that is jointly operated by the Animal and Plant Health Inspection Service (APHIS) and PIO personnel. Upon completion of a proposed "germplasm" building at the site of the new Beltsville quarantine facility, these quarantine and plant introduction activities will be consolidated with the fruit, potato, sweet potato, and sugarcane virus indexing programs. The collective quarantine facility is referred to as the National Plant Germplasm Quarantine Center (NPGQC).

C. Regional Plant Introduction Stations (RPIS)

The Introduction Unit of USDA had no centralized facilities for maintenance and preservation of seed. Thus many irreplaceable plant materials, painstakingly collected in foreign countries were lost. Crucial legislation, The Research and Marketing Act of 1946 (Public Law 733), authorized the creation of regional plant introduction stations (Univ. of Georgia 1971). Subsequently, four stations were established under a

Memorandum of Understanding between USDA-ARS and the State Agricultural Experiment Stations (SAES) as follows:

a. The North Central Project, NC-7, was approved by the North Central Directors Association and by the Committee of Nine with allocation of funds in July 1947, and activated on December 1, 1947.
b. The Northeastern Project, NE-9, officially came into existence July 1948. The site approved was the New York State Agricultural Experiment Station, Geneva, New York.
c. The Southern Project, S-9, had been approved in 1947 for a site at the Georgia Experiment Station, Griffin, Georgia but funding was not provided until November 1949.
d. In July 1947, Washington State University, Pullman, Washington was designated as the site for the Western Project, W-6, Regional Station. However, funds originally allotted were insufficient and full scale operations were delayed until 1952.

Initially, Puerto Rico was affiliated with the Southern Region, Hawaii with the Western Region (but now allies with the Southern Region because of crop similarities), and Alaska with the North Central Region (now with the Western Region). The facilities and responsibilities at all four regional stations have been greatly expanded since their conception. They are responsible for maintenance of a wide range of plant species, and their advent helped stem the great losses of valuable germplasm that had been regularly occurring. Skrdla (1975) described the operation of the four regional stations and their advisory committees.

D. National Seed Storage Laboratory (NSSL)

Funds were appropriated in 1956 for the construction of the NSSL at Fort Collins, Colorado for long-term preservation of germplasm. Construction was begun in 1957, and the Laboratory was ready for operation in 1958. This base or "savings account" storage facility had the capability of maintaining rooms at 4°C and relative humidity at about 32% and three rooms at −12°C if needed. The original plan was to accommodate over 200,000 samples of agronomic, horticultural, and speciality crop seeds.

Seeds of old, obsolete cultivars, when available, were requested by NSSL. In addition, as new cultivars were released by federal or state agencies, or by commercial breeders, an invitation was extended to the developer to deposit seed. Today, in addition to the above there is emphasis to include open pollinated lines, inbred lines, genetic stocks, discontinued breeding lines, differential hosts for pathogens, cultivars/species for indexing viruses and for physiological studies, and reserve seeds of plant introductions. Scientific staff conduct research on various aspects of seed physiology to improve the Laboratory's long term storage capability.

The Laboratory is responsible for the preservation of a broader scope of germplasm than the regional stations, which were concerned primarily with preserving and distributing seed of foreign plant introductions. The regional stations and other working collections are the sources of working stocks of seed. NSSL has become the long-term storage site for the base collection and seedstocks are distributed only when there are no other sources available.

If viability drops during storage in the Laboratory, stocks are rejuvenated at a site where the crop is adapted and in such a manner that the new seed will retain the genetic characteristics of the original seed. Rejuvenation of the Laboratory's seed stocks is coordinated through the curators of the working collections. Each curator is responsible for seed increases of his stocks and for depositing samples in NSSL (see Chapters 4 and 6).

E. Crop Specific Collections—Seeds

1. National Small Grains Collection (NSGC). Researchers of various cereal crops soon realized the value of assembling and maintaining germplasm collections for research purposes. The National Small Grains Collection is the largest and most active of U.S. collections. Its colorful history dates back to 1894 with the introduction of four accessions of barley and 11 additional accessions in 1895 (Moseman and Smith 1985). M. A. Carleton enlarged the barley collecton as a result of his exploration trip to Russia in 1898 and a trip to the Paris Exposition in 1900. In 1923 and 1924, H. V. Harlan collected barley in Russia, Ethiopia, North Africa, and other areas. G. A. Wiebe and others collected barley germplasm in Ethiopia and other countries in later years.

According to J. G. Moseman (unpublished), cultivar tests with barley, oats, and wheat began on Department land on the Mall in Washington, D.C. in 1866 and 1867. A number of cultivars (more than 100 of wheat) had been assembled in sufficient quantity for these tests prior to 1866. The same Research and Marketing Act of 1946 that provided funds for establishing the four regional stations contained support for germplasm research and resulted in funds becoming available for the small grain working collection at Beltsville (Reitz 1976).

Rice workers did not receive additional funding in 1948; thus, the collection was maintained separately from the rest of the working collection until 1982. Rice production began in the southeastern U.S. in the 1600s (Sharp et al. 1987). According to Adair et al. (1975), S. A. Knapp travelled to Japan in 1899 and returned with 10 tons of Kiushu rice. In the fall of 1901, he journeyed to Japan, China, India, and the Philippines to study rice production. He arranged before his return in 1902 for the introduction of numerous cultivars of rice from the countries visited. M. A. Carleton secured a collection of rice cultivars from foreign exhibitors at the Louisiana Purchase Exposition, St. Louis, Missouri in 1904.

Although storage facilities did not exist and frequent regeneration efforts were often neglected, the value of early introductions should not be underestimated. For example:

C.M. 67 barley—contains California Mariout and CI (Cereal Investigations number) 2376 (Ethiopia-1923) in parentage. CI 2376 contributed resistance to Barley Yellow Dwarf Virus (BYDV) and scald. Grown in San Joaquin Valley, coastal valleys, southern California, and late planting in Sacramento Valley (1974 varietal listing). In 1986, C.M. 67 was still growing on 6.4% of California barley acreage (J. G. Moseman unpublished).

Milton (CI 4966) barley—introduced from Russia in about 1936. Now the only source of complete resistance to loose smut and is used worldwide.

Ethiopian barley—only sources of high resistance to BYDV. In 1951, about 109 barley introductions from Ethiopia were identified as being highly resistant to BYDV in California. This resistance has held up in England, South America, and other countries. Most of these lines were introduced from 1917 to 1924. Benton (CI 1227) now grown in Oregon was introduced in 1917. BYDV, a serious present day disease of wheat and oats, has less impact in barley because the Ethiopian introductions are used in the parentage of new cultivars.

Our story of important cereal introductions would not be complete without mention of PI 178383, a wheat introduction collected in 1948 from eastern Turkey. PI 178383 had little agronomic appeal when grown for increase and preliminary evaluation. However, later testing of this line at Pullman, Washington for disease reactions showed multiple-resistance to races of stripe rust, common bunt, and dwarf bunt and useable tolerance to flag smut and snow mold (Univ. of Georgia 1971). For several years, this PI appeared in the parentage of all wheat cultivars grown in the northwestern United States.

The reorganization of ARS in 1972 brought the small grain and rice collections into the Germplasm Resources Laboratory. The two collections were merged in 1982. In 1988, the NSGC was moved from Beltsville to Aberdeen, Idaho, the site of the spring increase nursery for over 40 years.

2. Soybean (*Glycine max*) **Collection.** Although soybean is one of the real success stories of plant introduction, little attention was given to the preservation of soybean germplasm until the establishment of the collection in 1949. Its objective was "to collect and maintain all significantly different soybean strains from throughout the world with emphasis on the landraces of eastern Asia, where the soybean originated" (Bernard 1983; Bernard et al. 1987). Maturity groups provided a logical basis for determining which accessions would reside at Soy North, Urbana, Illinois (Groups 000 through IV) and at Soy South, Stoneville, Mississippi (Groups V through X). An effort was made in 1949 to salvage all available strains from USDA, State, and Canadian experiment stations, and this yielded 1,524 PI strains or domestic cultivars derived from PI strains.

Explorations by Meyer, Dorsett, and Morse in China, Japan, Korea, and Russia during the years 1906–1932 yielded 5,534 soybean accessions. None of the original PIs (114) from 1906 to 1917 were saved; however, 24 PI-derived cultivars are part of the collection today. Interestingly, six cultivars from northeastern China which were widely grown in 1930s and early 1940s plus five others have been the basis for all of the widely grown cultivars in northern U.S. (Bernard, 1983).

Wild perennial Glycine species pose a challenge for efficient long-term maintenance and effective utility in soybean improvement research. Bernard and Juvik (1988) detail the composition of the perennial Glycine collection.

3. Flax Collection. The flax plant (*Linum usitatissimum*) is as the species epithet *usitatissimum* implies "most useful" and ancient (Dillman 1953). The first entry in the germplasm collection was recorded in 1912 but research activity began before 1889. H. L. Bolley went to Russia in 1903 and to other European countries to obtain seed samples and to study the flax industry. In 1906, flax improvement by plant selection was started in North Dakota by the Office of Cereal Investigations in a cooperative federal-state program. Dillman (1953) indicates that 260 cultivars and strains were available from the collection accession list in 1925. The collection was managed by the Division of Cereal Crops and Diseases. The collection grew to more than 1300 accessions by 1950. Classification nurseries were established over the period of 1925 to 1941 in St. Paul, Minnesota; Bozeman, Montana; Mandan, North Dakota; San Antonio, Texas; and El Centro, California.

With the concentration of the field research in the upper Midwest, the collection was maintained for many years at St. Paul and later in 1974 moved to Fargo, North Dakota where it resides today. The formal collection had its start in 1912 and now consists of 2,659 accessions including about 75 fiber types all of which have been evaluated for descriptors established in 1946. Damont (CI 3), a cultivar from USDA's program in Minnesota, is the oldest accession in the collection with its entry in 1912.

4. Cotton (*Gossypium* spp.) Collection. Cotton expeditions from the early 1900s to the early 1960s formed the base for the cotton germplasm collection of today (Percival 1987). The earliest cotton collection appears to be a living collection of West Indian species assembled by von Rohr at St. Croix, Danish West Indies (now Virgin Islands) in 1781 (Fryxell 1985; Agr. Res. Service-USDA 1974).

During the first decade of 1900, several persons collected cotton germplasm in Mexico and Central America, the so-called center of variability of *G. hirsutum*. Collins and Doyle collected a stock in Chiapas, Mexico which gave rise to the Acala cotton. This type is widely grown in irrigated areas of west Texas, New Mexico, Arizona, and California. Likewise, Cook collected a special type in Guatemala called Kekchi. Paymaster company cultivars trace to this type.

Except for visits to the Mexican states of Sonora and Sinaloa, there was a complete dearth of further organized plant explorations for cotton germplasm until 1946. Subsequently Richmond and Manning made extensive collections in Mexico, Guatemala, and El Salvador. Other more current field collections have been listed/described (Agr. Res. Service-USDA 1974; Percival 1987). Catalogs listing cotton germplasm were published in 1956, 1974 (Agr. Res. Service-USDA 1974) and in 1987 (Percival 1987). The national collection of *Gossypium* germplasm, now held at College Station, Texas, provides a broad array of genetic diversity and includes the following:

Obsolete variety collection of *G. hirsutum*.
Texas Rose collection (*G. hirsutum*).
Asiatic collection (*G. herbaceum* & *G. arboreum*).
Wild species collection (wild diploid and tetraploid cottons).
Genetic marker collection (*G. hirsutum*).
Cytological collection (monosomes, telosomes, translocations, and duplication-deficiency stocks of *G. hirsutum*).

Fryxell (1985) described several successful uses of cotton germplasm for disease and insect resistance. While not detected in *G. hirsutum* germplasm, resistance to cotton rust was found in both *G. anomalum* and *G. arboreum*. Breeding techniques of interspecific hybrids, artificial polyploids, backcross schemes, and continuous screening for resistance culminated in the transfer of rust resistance to agronomically acceptable germplasm of *G. hirsutum*. Now, rust resistant cottons are available for use wherever cotton rust is a problem.

Another disease problem, bacterial blight, has largely been solved by identification of multiple sources of resistance and subsequent incorporation into cultivars.

Success with insect resistance has been more difficult. Changing the growth habits and morphology of the host plant has helped minimize losses caused by the boll weevil.

5. Other crop-specific seed collections. These evolved through the concerns and interest of commodity groups and individual researchers. Space does not permit us to trace their history. The caretakers of these collections have contributed much to crop improvement and basic research.

6. Inter-Regional Potato Introduction Station. The potato arrived in the United States in 1622 after its introduction to Bermuda in 1613 by English colonists. U.S. collectors began the field search for wild tuber-bearing *Solanum* species in the 1930s for use in research programs. Many of these introductions vanished because of diseases, failure to tuberize, and lack of maintenance facilities. In 1947 the Potato Association of America helped develop plans for a cooperative potato program with the main operation at Sturgeon Bay, Wisconsin and associated research at Madison. Implementation of the plans for the facility through the 1946 Research and Marketing Act legislation proceeded.

The station, which is supported by states of all four U.S. Regions, the Wisconsin Agr. Exp. Sta., and ARS, became operational in 1950. The primary objectives of this Inter-regional Project (IR-I Project) are to:

1. introduce, preserve, and classify the wild and cultivated tuber-bearing *Solanum* species, and
2. distribute introductions to potato breeders and other scientists for research purposes (Hanneman and Ross 1978).

The germplasm is preserved primarily as true seeds.

Foreign introductions became part of the parentage of 120 American potato cultivars during the period of 1932–1975 (Univ. of Georgia 1971). Bamberg and Hanneman (1987) reported some contributions of germplasm accessions in the potato collection to research and cultivar improvement in the United States. For example, they indicated that, as part of the parentage, 34 U.S. cultivars developed during 1977–1986 contained one or more *Solanum* species in addition to *S. tuberosum*. These species have provided resistance or tolerance to frost, nematodes, insects, viruses, extreme heat, late blight and other diseases. The potato research community through individual scientists, technical committees, and foreign cooperators have developed extensive field collecting plans and have implemented several phases of the plans.

III. OPERATION OF NPGS

The NPGS describes its mission as follows:

The National Plant Germplasm System (NPGS) provides the genetic diversity necessary to improve crop productivity and to reduce genetic vulnerability in future food and agriculture development, not only in the United States but for the entire world. The NPGS acquires, maintains, evaluates, and makes readily accessible to plant scientists a wide range of genetic diversity in the form of seed and clonal germplasm of crops and potential new crops.

To accomplish the overall mission, all of the elements of NPGS must function in harmony as a whole since interactions among the elements affect the operation of the entire system (Fig. 1.6). Each element has certain functions to perform in order to meet its specific objectives. These include acquisition, exchange, evaluation, preservation, distribution, data management, and training. Let us look at how these functions are accomplished through the major elements of the System.

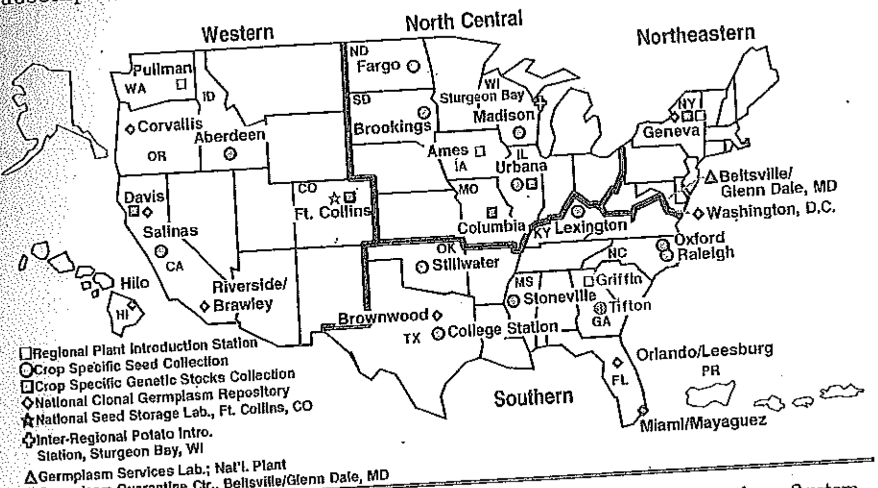


Fig. 1.6. Approximate location of the elements of the National Plant Germplasm System.

A. Germplasm Services Laboratory (GSL)

This laboratory is part of the Plant Sciences Institute, USDA-ARS, Beltsville. The laboratory mission encompasses national activities of exchange, exploration, liaison on quarantine matters, ecogeographic studies, management of the national Germplasm Resources Information Network (GRIN) database, coordination of Crop Advisory Committees (CACs), and closely related activities. Staff of GSL interact extensively with NPGS personnel, U.S. scientists, foreign institutes and scientists, and with other USDA and U.S. government agencies.

1. Plant Introduction Office (PIO). The primary objective of PIO is to keep a continuous flow of diverse, well-documented plant germplasm moving into crop improvement programs in the United States and abroad

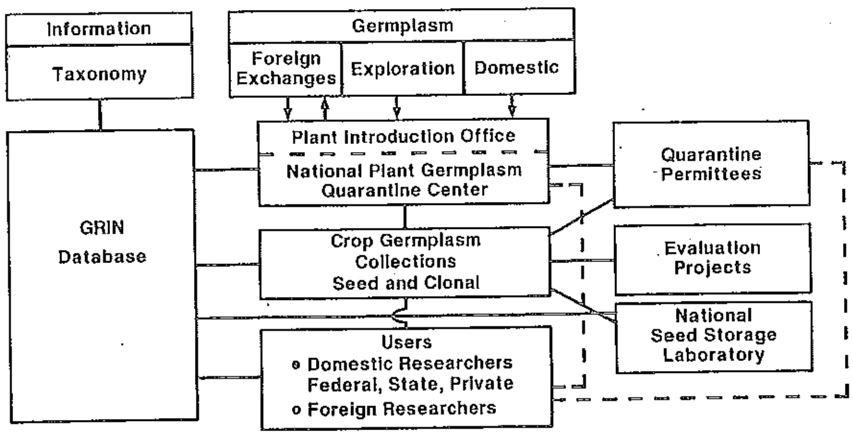


Fig. 1.7. The primary flow channel in the United States for imports and exports of plant germplasm and associated information.

through a well established flow channel (Fig. 1.7). The functions involved include:

- Coordination of the acquisition and exchange of plant germplasm
- Documentation of passport data and assignment of Plant Introduction (PI) numbers
- Publication of the USDA Plant Inventory
- Liaison on quarantine matters
- Assistance with quarantine and distribution of plant materials collected through plant exploration

a. *Acquisition and Exchange*—Plant germplasm for NPGS is acquired through exchanges, exploration (domestic and foreign), special projects and agreements, gifts, and travelers. PIO and individual U.S. scientists have many contacts worldwide which result in numerous exchanges of plant materials. Not all of the introduced materials are incorporated into NPGS. Some are genetically unstable, some poorly documented, and some are passed on to scientists who are requested to identify useful items and feed them into the system. Since quarantine regulations restrict the introduction of relatively few crop species, there are large numbers of accessions that are introduced directly into researchers' programs.

Most of the collections in the U.S. have at least some accessions that have not been assigned PI numbers. The National Small Grains Collection, for example, holds several thousand accessions under CI numbers. The clonal repositories in general prefer to establish and to obtain some evaluation data before requesting PI numbers. Thus, the annual number of new PI entries into NPGS does not include all new entries into NPGS within a given year. The number of new PIs each year has fluctuated

Table 1.2. PI number assignments for 1978 through 1987.

Year	No. of PI Assignments	PI range
1978	10,657	420807–431463
1979	5,527	431464–736990
1980	15,081	436991–452071
1981	12,792	452072–464863
1982	10,970	464864–475833
1983	7,263	475834–483096
1984	11,030	483097–494127
1985	6,020	494128–500148
1986	6,069	500149–506218
1987	8,056	506219–514275
Total	93,465	
Average/ year	9,347	

Table 1.3. Distribution during 1983–1987 of plant materials to foreign countries through the NPGS exchange program.[1]

Year	Total number of items	No. of shipments	No. of countries	Cereal disease nurseries items	Cereal disease nurseries % of total
1983	110,686	2,049	121	46,269	42
1984	111,122	2,096	119	48,118	43
1985	95,854	1,853	123	48,196	50
1986	71,494	1,488	115	32,867	46
1987	62,615	1,450	104	7,055	11
Average	90,354	1,787	116	36,501	38

[1]Includes only those plant materials sent abroad through the USDA National Plant Germplasm Quarantine Center, Beltsville.

widely over the last 10 years from 5,527 in 1979 to 15,081 in 1980 with a 10-year average of 9,347 (Table 1.2). Increasingly, more domestic accessions are being added.

The payoff for plant germplasm is its use in research programs and ultimately in an improved form in farmers' fields. Exchange is the primary mechanism for adding diverse germplasm to NPGS. While the U.S. provides considerably more items each year to other countries than it receives, the introduction of foreign germplasm ranks high on the priorities of the national program. Note that the number of items sent abroad has declined steadily for the past three years (Table 1.3). Several factors are involved. As more information is recorded and computer documented, scientists can be more selective in respect to number of accessions and to specific traits. Also more germplasm stocks are being added each year to national and international collections thereby lessening the demands on the U.S. program. The Cereal Disease Nursery program which has in some years constituted almost half of the items sent abroad is undergoing a substantial reduction partially as a result of the CIMMYT international cereal effort. Exchange data presented here include only those items that are moved through the NPGS flow channels at Beltsville.

For the two way movement (exchange) of plant germplasm, the NPGQC is a convenient flow channel. APHIS officials are responsible for inspecting incoming and outgoing materials to assure that the U.S. and importing countries' quarantine regulations are met. PIO helps expedite the rapid movement and recording of pertinent information.

Exchange of plant germplasm is the lifeline of national and international programs. The policy of the U.S. is for free exchange of plant germplasm in small experimental quantities for research purposes. Plant germplasm is an essential ingredient of crop improvement programs in all countries.

PIO through the Plant and Seed Materials Project, which is funded by the Agency for International Development (AID), provides plant germplasm to AID missions and cooperating institutions in developing countries. Usually U.S. cultivars are provided in larger quantities than in the regular exchange program. The activity of this project for the past five years is summarized in Table 1.4. Plant materials are supplied in forms such as seed, cuttings, tubers, offshoots, and grafted trees. This project benefits the U.S. program through establishment of new contacts, travel, and identification of germplasm collections in cooperating countries.

b. *Documentation of Passport Data and PI Number Assignment.* Information that travels along with plant germplasm accessions is referred to as passport data. These data are computer documented for all accessions that are to be included in NPGS. The unique identifier of

Table 1.4. Distribution during 1983–1987 of plant materials to AID missions and cooperators through the Plant and Seed Materials Project.[1]

Year	Items	Shipments	Countries
1983	776	125	50
1984	3900	116	38
1985	3198	106	41
1986	1416	105	37
1987	518	85	34
Average	1962	107	40

[1]Longstanding project between the USDA-ARS Plant Introduction Office and the U.S. Agency for International Development that dates back to 1955.

NPGS, the PI number, is assigned. The GRIN database accommodates the various passport-data descriptors (Table 1.5). Data sheets and collector notebooks are tailored to accommodate the descriptor fields for passport data. Some data are transcribed electronically. The use of documentation aids such as bar codes reduces the amount of transcriptions and therefore reduces error. The amount of passport data varies greatly from little more than the seed source and name of the plant to detailed descriptions of field collected items, cultivars, and special stocks.

Beginning in 1987, all plant materials [cultivars (CV), germplasms (GP), and parental lines (PL)] that are registered by the Crop Science Society of America (CSSA) are assigned PI numbers and seed deposited at the appropriate working collection as well as at NSSL. Genetic stocks (GS) are to be added in 1988. In order to easily identify CSSA registered

Table 1.5. Descriptors for documentation of passport data.

- Taxonomy
  - Genus, species, authority, family, common name
- Crop category
- Donor
  - Name, Institute, address
  - Remarks
  - Identification Number
- Origin
  - Country, state or province
  - Institute, address, identification number
- Cultivar name
- Pedigree
- Local name
- Collection date
- Collector name and identification number
- Other identification, source, group
- Locality
  - Habitat, location
- Latitude/Longitude coordinates
- Elevation
- Remarks
  - Plant characteristics, uses
- Special attributes
  - Pest resistance, cold tolerant
- Received as
  - Scientific name
- Coded items
  - Life form—annual, biennial, perennial
  - Improvement status—wild, cultivated, landrace, cultivar
  - Form received—seeds, plants, cuttings
- Destination
- Records

materials and to selectively retrieve data about them, the special letter codes are used. Each item falls within a Crop Science Registration (CSR) group such as oats, soybeans, and others. The CV, GP, PL and GS designations are added to the database. After the registration manuscript is published, the Crop Science reference is added to each PI record on the database (White et al. 1988). An example of a PI record for a Crop Science registration cultivar is shown in Table 1.6.

c. *Publication of the USDA Plant Inventory.* PI numbers have been assigned and inventories published continuously since 1898; The Plant Inventories represent a permanent historical record of plant materials that have been entered into NPGS. They are not lists of availability, which is determined by personnel at the working collections.

Since 1979, passport data documentation and PI number assignment have been automated. The GRIN database allows computer generation of an entire Inventory except for the cover and preface pages. Documented data and the index are edited by PIO staff. After editing, the complete manuscript is submitted for publication. In most years there is only a 3–5 month lag from the last PI number assigned in December and the publication of the inventory. Inventories are distributed to land grant agricultural universities, to NPGS sites, to libraries, to literature exchange institutions in various countries, and to U.S. and foreign research cooperators.

Inventories are structured chronologically by PI numbers. Future plans

Table 1.6. Plant Introduction (PI) number record for a Crop Science registered cultivar of peanut (*Arachis*).

PI 506237.	*Arachis hypogaea* L. FABACEAE Peanut
Donated by Simpson, C. E., Texas Agricultural Experiment Station, Texas A&M University, Stephenville, Texas, United States. Cultivar developed by C. E. Simpson, O. D. Smith, and D. H. Smith, Texas Agricultural Experiment Station, Stephenville, College Station, and Yoakum respectively. Received January 15, 1987.	
PI 506237	donor id: TP-107-3-8. origin: United States. cultivar: LANGLEY. pedigree: Florunner/PI 109829. other id: CV-31. group: CSR-PEANUT. litref: Crop Sci. 27(4):816–817. 1987. remarks: Plant early maturing. Seeds runner market type. Similar to Florunner in yield, plant characters, shellability, blanchability, shelf-life, protein content, and oil content but one to two weeks earlier maturing. Cultivar. Seed.
Destination:	Southern Regional PI Station, Griffin, GA 30223, United States; National Seed Storage Laboratory, Colorado State University, Fort Collins, CO 80523 United States.
Records:	Simpson, C. E., Texas Agricultural Experiment Station, Box 292 Stephenville, Texas 76401 United States.

call for microfiching plant inventory data in different formats such as by PI numbers, by scientific name, and by origin/source. The printed volumes are bulky and heavy. Microfiche would cut down on mailing costs and on space conservation for storage. Compact computer disks may offer even greater efficiences in the future. The front cover of USDA Plant Inventory 196 for 1987 is shown in Fig. 1.8.

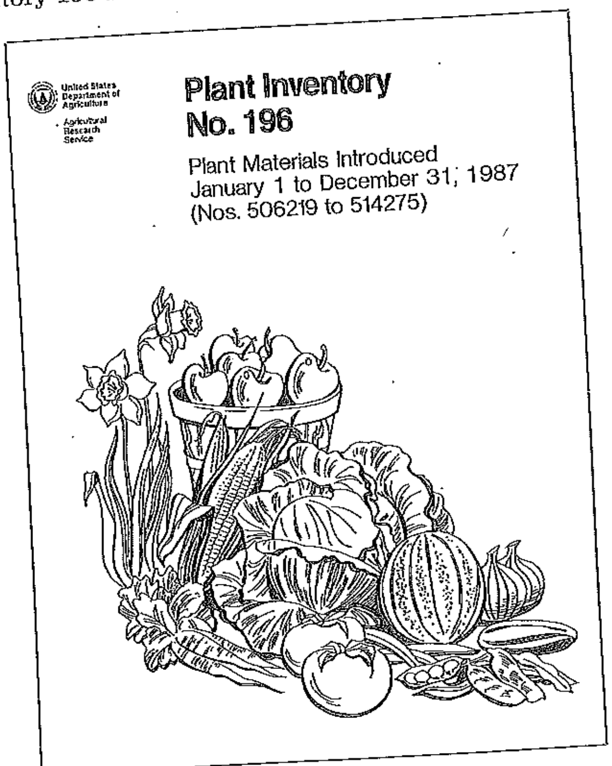


Fig. 1.8. Frontspiece for USDA Plant Inventory No. 196 for 1987.

d. *Liaison on Quarantine Matters.* Most countries have quarantine regulations that were developed to safeguard regularly cultivated crops from possible ravages of introduced exotic pests. When a country lacks the resources or lacks procedures for handling restricted items, invariably the movement of plant germplasm into research programs will be hampered. PIO provides a linkage between scientists and U.S. quarantine officials for the importation and exportation of plant materials. There are two main reasons for this activity:

1. To assure that the quarantine requirements of the importing country are met, and

2. To help expedite the rapid movement of the materials into researchers' programs.

Scientists that wish to import or export plant germplasm should be aware of the importing country's requirements. U.S. scientists can obtain this information by contacting PIO or APHIS. NPGS is striving to streamline the systematic introduction and quarantine increase of restricted materials. Recently, the Federal Experiment Station, St. Croix, U.S. Virgin Islands was approved for the field increase of quarantined sorghum germplasm. Hopefully, prohibited crops like maize, pearl millet (*Pennisetum* spp.), and rice will be approved by APHIS for quarantine increase at the St. Croix Station in the near future.

Problems in meeting import requirements of other countries are increasing. A phytosanitary certificate cannot be issued unless the import requirements can be fully met. Perhaps the most commonly encountered problem is the requirement of field inspection of the parental planting. Import permits are often not provided even though required. Other additional declarations (ADs) such as that a particular disease does not occur in the U.S. or area of production, virus-free certified, or treatment with specific pesticides are frequently difficult to meet. U.S. researchers, especially curators of plant germplasm, should be aware of import requirements of other countries. This awareness is particularly important for highly perishable materials such as plants, cuttings, and tissue cultures. Scientists are encouraged to check before shipping with local state and federal quarantine officials, APHIS officials at the USDA Plant Germplasm Quarantine Center, or with the Plant Introduction Office about the quarantine status of specific plant materials.

2. Plant Exploration and Ecogeographic Studies. Activities related specifically to plant exploration involve assessing genetic diversity of germplasm collections currently held by the NPGS and other repositories as compared to total genetic diversity that may exist in nature. A gene pool concept is employed to compare the potential utility of wild crop relatives for plant breeding. Based on priorities developed with the gene pool concept, gaps in current germplasm collections are identified as indicated by inadequate coverage of total genetic diversity. Plant explorations are planned based on a need to acquire germplasm to fill those gaps. Explorations are carried out using ecogeographic guidelines so as to collect maximum genetic diversity with a minimum number of samples. While explorations are usually crop specific, pre-trip plans are often made to collect wild relatives of other crops occurring in the same area as the target crop. Assistance in planning and executing plant exploration is provided to other collectors undertaking expeditions for the NPGS. Close contacts are also maintained with botanists and other plant explorers traveling to places where germplasm sought by the NPGS is known to occur. These contacts can sometimes acquire germplasm which would otherwise require a separate NPGS expedition.

In addition, the ecogeographic unit in GSL investigates problems in genetic diversity and collection coverage. Automatic data processing techniques are used to develop long-range strategies for increasing the genetic diversity of U.S. collections. Current projects include assessment of highest priority needs among major crops, construction of geographical information and expert systems to map optimal itineraries for collection trips, and investigation of the most urgent needs from repositories in selected countries.

ARS has annually recurring funds for foreign and domestic explorations. Scientists submit proposals according to a prescribed format (see Chapter 3). The proposals are sent through a review system of Crop Advisory Committees, Regional Technical Committees, Operations Committee, and lastly an ARS Germplasm Matrix team. Assistance to collectors relative to contacts, quarantine, collection permits, distribution of samples, and other factors is provided by scientists and by support staff of the Germplasm Services Laboratory (GSL). GSL staff may also directly participate in explorations. Field data are collected on data sheets that conform closely to the passport data area of the GRIN database. This greatly expedites data entry and speeds up the passport data documentation and PI number assignment. U.S. scientists sometimes receive special funds for exploration or may join other collecting expeditions sponsored by other organizations such as The International Board for Plant Genetic Resources (IBPGR). The quarantine inspection of all incoming materials regardless of whether by exploration or through exchange is essential.

The various crop advisory committees are charged with determining collection gaps and specific germplasm needs of the particular crop or crops for which they provide technical expertise. Priorities for exploration are influenced by several factors such as the completeness of the collection, the need for specific traits for significant advancement, the threat of immediate loss of old landraces and wild relatives in centers of diversity because of agricultural or urban development, and political factors affecting future availability of germplasm.

For foreign materials, collectors must adhere to U.S. quarantine regulations, therefore interactions among the crop curators, the Plant Introduction Officer, the National Plant Germplasm Quarantine Center, and the collectors must take into consideration the quarantine aspects and the initial distribution of the material upon entry into the United States. Guidelines for conducting explorations and listings of completed explorations are given in Chapter 3 of this volume of *Plant Breeding Reviews* and in the so-called 20-year Report (Univ. of Georgia 1971).

3. Database Management Unit. Personnel at various collection sites developed their own manual documentation methods over many years, and more recently different kinds of computer database systems. As examples, PIO used a paper tape word processor to generate PI number records for many years until conversion to a Datapoint computer system in 1979, and the Western Regional Plant Introduction Station used an automated data processing system in 1959 which was updated and modified to a computer system in 1963.

As germplasm collections expanded and the need for easily retrievable information increased, the need to develop a national information system for NPGS became apparent (see Chapter 2). The initial step in this direction occurred in 1976–77 as a feasibility study. Results of that study showed that a fragmented information system existed but it lacked the organization, linkage, uniformity, and staffing to meet the requirements of the users and NPGS operational entities (Agr. Res. Service-USDA 1987). Subsequently, the Germplasm Resources Information Project (GRIP), a joint private/federal/state venture emerged and was supported by ARS through a Cooperative Agreement with Colorado State University. In July 1983, the database program received its present name—the Germplasm Resources Information Network (GRIN)—and ARS assumed the responsibility to complete, implement, upgrade, and maintain the database (Agr. Res. Service-USDA 1987; Perry 1988; Perry et al. 1988).

At this writing GRIN software programs have had two major revisions aimed at making the system more user friendly and at providing additional capabilities for the sites. Data from most NPGS sites have been loaded onto the database. Most of the NPGS sites were "on-line" during 1988. In addition to handling passport, evaluation, and inventory information, there is a taxonomy file that is expected to surpass 50,000 scientific names. This file encompasses most of the 3000 species in a useful working checklist compiled by Terrell et al. (1986). Germination test results and geographical files are also maintained on the database. GRIN is a centralized computer database and consists of Prime Computer No. 9955 with the capacity of 2 billion characters of data or data for an estimated 550,000 accessions. It is user-friendly and easily accessed through telecommunications. The main purpose of GRIN is to serve as a central repository for information about germplasm in NPGS.

B. Plant Quarantine Regulations and Procedures

Quarantine regulations are enacted to provide safeguards against the introduction of pests that adversely affect crop production and storage. White (1987) states that the following underlying premises should apply to quarantine measures:

1. Based on sound biological principles with objectives of preventing the introduction and spread of pests. The objectives should be reasonably achievable through adequate law, authority, and expertise.
2. Should not be used to hinder trade or exchange of plant germplasm.
3. Should be readily changeable as conditions change and more facts are known.
4. Requires well-informed quarantine officials and the cooperation of scientists and the general public.
5. Used in conjunction with other domestic pest management programs.

There are three U.S. categories of quarantine (Waterworth and White 1982; Parliman and White 1987). These are:

1. Restricted—An inspection at the port of entry satisfies the quarantine requirement for most plant species in this category. Permits may be required especially if more than 12 plants are involved. The main objective of this category for low-risk items is to insure official inspection of the imported plant materials. Most forage, vegetable, and flower species are in the restricted category.
2. Postentry—Postentry as a term is often incorrectly used. As a quarantine category, specific conditions are detailed for handling such materials. Usually, inspections during two active growing seasons are required. Certain distances between quarantined and nonquarantined items must be maintained. A postentry permit allows individuals to observe the materials but they cannot distribute them until formally released by quarantine officials. Federal and State approval are required for postentry permits.
3. Prohibited—This is the most restricted category. Federal permits are required for any plant species in this category. The imposing of this restriction varies widely depending on the crop, the plant parts involved (e.g. seeds, plants, cuttings, bulbs), and the source location.

Researchers cannot obtain permits for prohibited category imports of some crops such as *Malus, Prunus, Pyrus*, tuber-bearing *Solanum* (potato), and roots of *Ipomoea* (sweet potato). These items, with few exceptions, must be virus-indexed through the program of the National Plant Germplasm Quarantine Center. However, persons with proper expertise and facilities can obtain permits for most of the prohibited seeds category. A partial listing of plant species that fall under the postentry and prohibited categories is given in Table 1.7.

Table 1.7. Examples of Crops in the Post-Entry and Prohibited Quarantine Categories[1]

Crop	World Source	Requirements	Pests
		Seeds	
Arachis (peanut)	China, People's Rep. of, Philippines, Thailand	Prohibited, permit[2]	Stripe virus
Gossypium (cotton)	All countries	Restricted[3], requires acid delinting or funigation	Pink bollworm, viruses, various diseases
Oryza (rice)	All countries	Prohibited, permit, detention nursery	Smuts, viruses, various diseases
Pennisetum (also *Eleusine, Echinochloa, Panicum, Setaria*)	Africa, Asia, Brazil, Bulgaria, USSR	Prohibited, permit	Smuts
Prunus (except resistant species)	All countries	Prohibited, AD[4] on permit	Plum pox virus
Solanum (tuber-bearing species)	All countries except Canada	Prohibited, permit, share seeds with quarantine officials	Viruses
Sorghum	Africa, Asia, Australia, Bulgaria, USSR	Prohibited, permit	Ergot, loose smut
Triticum	Asia, eastern and southern Europe, parts of Africa, Australia, Guatemala,	Prohibited, permit	Flag smut
	Afghanistan, India, Iraq, Mexico, Pakistan	Prohibited, permit	Karnal bunt
Zea	Asia, Africa, Australia Oceania, Bulgaria, USSR	Prohibited, permit	Downy mildew, witchweed

[1]Adapted and updated from Waterworth and White (1982), Parliman and White (1985), White (1987) and Animal and Plant Health Service-USDA (1982).
[2]Only one permittee currently approved.
[3]Status under review.
[4]Additional declaration (AD) required on exporter's phytosanitary certificate.
[5]Only two permittees currently approved.

Crop	World Source	Requirements	Pests
	Vegetative Propagules		
Acer (maple)	Europe, Japan	Prohibited, permit	Leaf disease (*Xanthomonas*), maple-variegation virus
	All other countries except Canada	Postentry permit	
Actinidia (kiwi)	Taiwan, Japan	Prohibited, permit	Rust
	All other countries except Canada, Australia, New Zealand	Postentry permit	
Bambusa, other genera bamboo	All countries	Prohibited, permit	Diseases
Castanea (chestnut)	All countries except Canada	Postentry permit	
Chrysanthemum (mums)	Argentina, Brazil, Chile, Europe (except Great Britain), South Africa, Uruguay, Venezuela, all countries entirely or part between 90 and 180 degrees East longitude	Prohibited, permit	White rust
	All other countries except Canada	Postentry permit, AD[4]	
Citrus	All countries	Prohibited, permit[5]	Viruses
Cocos (coconut)	All countries except Jamaica		Lethal yellowing, cadang-cadang disease
Dianthus	All countries except Canada, Great Britain if AD[4] lacking	Postentry permit	Carnation-etched ring streak and fleck viruses
Fragaria (strawberry)	Australia, Austria, Czech., France, G. Britain, Italy, Japan, Lebanon, The Netherlands, New Zealand, Northern Ireland, Rep. of Ireland,	Prohibited, permit	Red stele disease

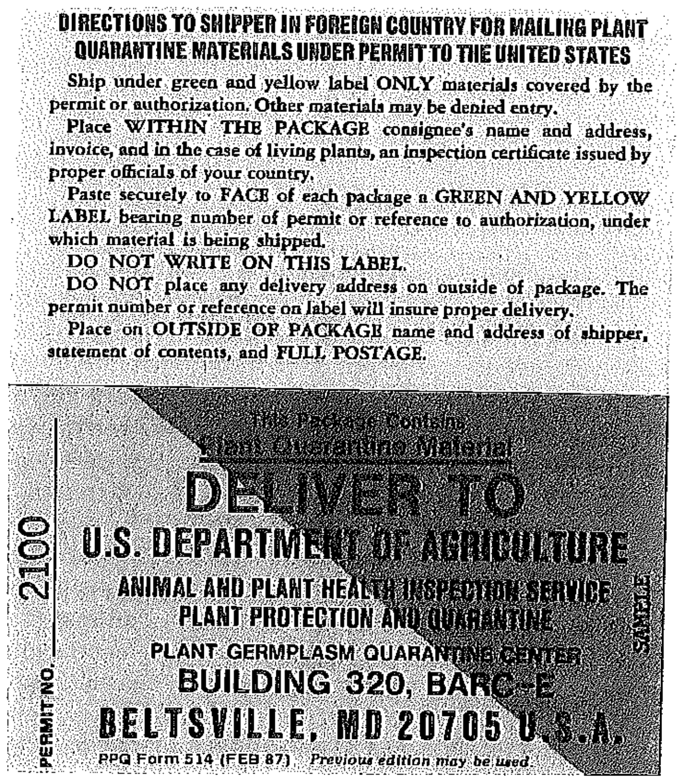
Crop	World Source	Requirements	Pests
Fragaria (cont.)	Switzerland, USSR		
	All other countries except Canada	Postentry permit	
Grasses (various genera)	All countries except Canada	Prohibited, permit	Viruses/virus-like diseases
Ipomoea (sweet potato)	All countries except Canada	Prohibited, NPGQC permit only	Viruses
Malus, Prunus & *Pyrus* (apple, pear, cherry, peach, almond, etc.)	All but few with approved virus-free certification	Prohibited, NPGQC permit only	Viruses
Morus (mulberry)	India, Japan, Korea, Thailand, USSR, People's Rep. of China	Prohibited, permit	Dwarf agent, curly little mosaic, others
	All other countries except Canada	Postentry permit	
Phoenix (date palm)	All countries	Prohibited, permit	Lethal yellowing, cadang-cadang disease, others
Pinus (pine)	Europe	Prohibited	Douglas fir canker
	Europe and Japan	Prohibited	Rust
Ribes nigrum (black currant)	Australia, British Columbia, Europe, New Zealand	Prohibited, permit	Black currant reversion agent
	All other countries except Canada	Postentry permit	
Rosa spp. (roses)	Australia, Italy, New Zealand	Prohibited, permit	Rose Wilt
	All other countries except Canada	Postentry permit	
Rubus (blackberry, raspberry)	All countries. Ontario, Canada, & Europe require AD	Postentry permit unless AD[4] from Ontario, Canada	Stunt virus

Crop	World Source	Requirements	Pests
Salix (willow)	Germany (FRG & GDR) Great Britain, The Netherlands	Prohibited, permit	Watermark disease (*Erwinia*)
	All other European countries	Postentry permit	
Solanum (tuber-bearing species)	All except Canada	Prohibited, permit	Viruses
Sorbus (mountain ash)	Fed. Rep. of Germany, German Dem. Republic, Australia, Japan, New Zealand, Oceania, Philippines, People's Rep. of China	Prohibited, permit	M. ash varietation virus
	All other countries except Canada	Postentry permit	
Theobroma (cocoa)	All countries	Prohibited, permit	Virus & virus-like diseases
Vitis (grape)	All except Canada	Prohibited, permit	Viruses & diseases

Quarantine is an important ingredient of successful plant introduction programs. White (1987) likens plant introduction and quarantine to a marriage of necessity. Adequate safeguards to protect against the inadvertant introduction and spread of exotic and potentially dangerous diseases, insects, nematodes, and weeds should be built into any plant introduction program. At the same time, provisions for the systematic introduction of germplasm and adequate testing for possible pests is essential for the regular influx of genetically variable materials into crop improvement and basic research programs.

Kaiser (1983 and 1987) warns against the introduction of serious seed-borne diseases with plant germplasm and describes testing procedures to insure the production of healthy plant materials. Parliman and White (1985) describe in considerable detail the virus-indexing procedures used for testing imported germplasm of fruits, potatoes, and sweet potatoes in their review of the U.S. plant introduction and quarantine system. On the international scene, R. P. Kahn (1983) discussed the pathways over which pests and pathogens can move or be moved from country to country. He considered one of the pathways the import and export of seeds by the International Agricultural Research Centers. Various safeguards including those used by the Centers for *Phaseolus* (beans), *Triticum* (wheat), *Cicer* (chickpeas), *Cajunus* (pigeon pea), *Arachis* (peanut), and *Vigna* (cowpea) are discussed.

Laypersons and scientists need to be aware of the risk factors associated with species they intend to import. They need to obtain import permits and use quarantine import labels (Fig. 1.9). Materials to be sent directly to individuals should be given to federal or state quarantine officials for inspection regardless of the quarantine status of the materials. Materials exported to other countries should first be inspected by quarantine officials and be accompanied by a phytosanitary certificate. When the importing countries' requirements can't be met, a certificate will not be issued. In such cases, the importer will either have to obtain an import permit which waives the unmet requirement [usually an additional declaration (AD)] or work out special arrangements through the importer's quarantine service. PIO usually can provide assistance in properly resolving these problems.



DIRECTIONS TO SHIPPER IN FOREIGN COUNTRY FOR MAILING PLANT QUARANTINE MATERIALS UNDER PERMIT TO THE UNITED STATES

Ship under green and yellow label ONLY materials covered by the permit or authorization. Other materials may be denied entry.

Place WITHIN THE PACKAGE consignee's name and address, invoice, and in the case of living plants, an inspection certificate issued by proper officials of your country.

Paste securely to FACE of each package a GREEN AND YELLOW LABEL bearing number of permit or reference to authorization, under which material is being shipped.

DO NOT WRITE ON THIS LABEL.

DO NOT place any delivery address on outside of package. The permit number or reference on label will insure proper delivery.

Place on OUTSIDE OF PACKAGE name and address of shipper, statement of contents, and FULL POSTAGE.

This Package Contains
Plant Quarantine Material
DELIVER TO
U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE
PLANT GERMPLASM QUARANTINE CENTER
BUILDING 320, BARC-E
BELTSVILLE, MD 20705 U.S.A.
PERMIT NO. 2100
SAMPLE
PPQ Form 514 (FEB 87) *Previous edition may be used.*

Fig. 1.9. A sample quarantine import label with instructions for proper use. Permit No. 2100 is used primarily by the USDA's Plant Introduction Office.

Many countries including the United States have routine inspections of germplasm growouts by qualified quarantine officials or by their approved representatives. With effective inspection programs, import requirements are more readily met. Further, officials of as many countries as possible should strive for compatability in their virus-indexing programs that would allow the movement of much larger numbers of plant materials under postentry requirements. Acceptable compatibiliiy among many countries will be difficult to achieve, and must include constant monitoring, but would contribute greatly to the germplasm accessibility of *Citrus, Ipomoea, Malus, Prunus, Pyrus,* tuber-bearing *Solanum* and other crops.

In summary, federal and state quarantine officials work closely with scientists in NPGS to provide safeguards against the inadvertant introduction of serious pests with the importation of plant germplasm. A flow channel for the movement of imports and exports permits the routine inspection of plant materials and helps to insure that the importing countries' quarantine requirements are met. Systematic arrangements exist for handling most quarantined items but improvements are needed to shorten the quarantine period especially for fruit germplasm and allow more accessions to be rapidly tested and released for use in research programs.

International cooperation in obtaining greater compatability of virus-indexing procedures among nations is needed so that rigidly quarantine-restricted germplasm can be more accessible to research scientists.

C. Noxious Weeds

The Plant Quarantine Act of 1912 granted authority for regulation of all plant material imported from abroad because of plant pests. The Federal Noxious Weed Act of 1974 provided authority to regulate the introduction of known noxious weeds from other countries. Both Acts are administered by APHIS. USDA Directive 610.5 of June 7, 1979 entitled "Minimizing Risks of Releasing Weedy or Poisonous Plants" presents guidelines for handling the importation of noxious weeds for research and germplasm programs. Recipients of noxious weed seed are required to obtain federal and state quarantine permits (both federal and state approval) and interstate stickers must be placed on packages for interstate movement. Examples of an import permit and interstate shipment label are shown in Fig. 1.10.

Some noxious weed species are important components in germplasm collections. A notable example is *Avena sterilis* of which 5,946 accessions reside in the National Small Grains Collection. This species has been used extensively in the improvement of the common oat, *A. sativa*.

The following noxious weed species are included in U.S. plant germplasm collections:

Avena sterilis
Carthamus oxyacanthus
Chrysopogon aciculatus
Digitaria scalarum
Galega officinalis
Heracleum mantegazzianum
Imperata brasiliensis
Imperata cylindrica
Ipomoea aquatica
Ipomoea triloba
Ischaemum rugosum
Oryza rufipogon
Paspalum scrobiculatum
Pennisetum clandestinum
Pennisetum macrourum
Pennisetum pedicellatum
Pennisetum polystachion
Prosopis farcta
Rottboellia exaltata
(= *Rottboellia cochinchinensis*)
Rubus fruticosus
Rubus moluccanus
Saccharum spontaneum
Setaria pallidifusca
Urochloa panicoides

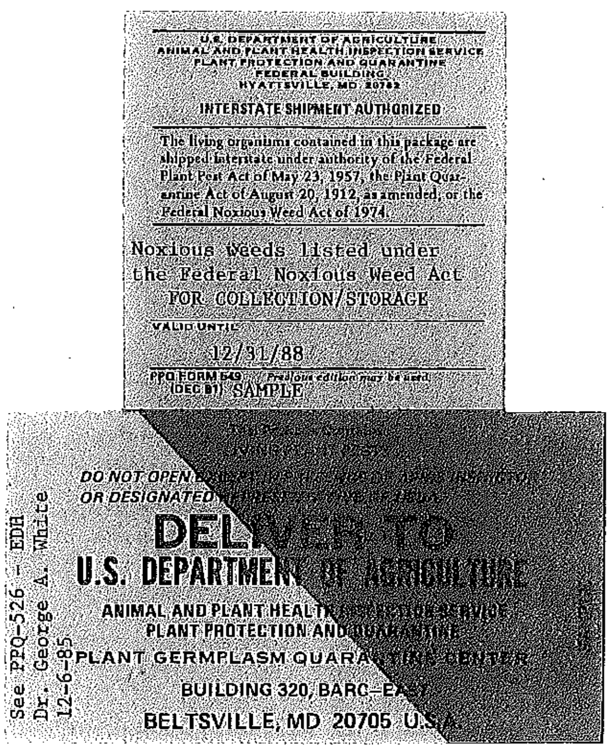


Fig 1.10. Sample import permit and interstate shipment label for noxious weeds.

For further information about rules, regulations, and species pertaining to noxious weeds, see 7CFR Part 360, Noxious Weeds, Federal Register Vol. 48, No. 87, 1982. The book by Holm and others (1979) about world weeds was a primary source of information for determining which species should be included in the 1983 Noxious Weed list.

D. Germplasm Working Collections

The objectives of working collections are essentially the same even though activities may vary greatly because of the nature of the species maintained. These objectives include germplasm acquisition, increase, evaluation, data documentation, maintenance, distribution, and training. Most include extensive service activities and some research especially related to evaluation and enhancement.

1. Seed Collections. Samples from exchanges, explorations, gift donations, special projects or agreements, and domestic research programs are inventoried and scheduled for seed increase and evaluation. Germination tests may be done in-house, through state seed laboratory arrangements, or by staff of the National Seed Storage Laboratory. Plantings are designed to be large enough to adequately represent the diversity contained in the original sample and to allow distribution for research and long-term storage (see Chapters 4 and 6). For many cross-pollinated and partially cross-pollinated species, special pollination control is necessary to maintain the genetic integrity of original stocks. Hence, techniques such as hand pollination, bagging, sibbing or caged insect pollination must be employed (Fig. 1.11).

Crop advisory committees (CAC) in close cooperation with IBPGR committees develop descriptor lists for the most important traits for which information is needed. These descriptors emphasize agronomic and horticultural traits of greatest importance to breeders, pathologists, entomologists, and other researchers. Botanical and morphological descriptors are used mainly for identification purposes. Some of the descriptor information is obtained at the seed increase site. Other data may be gathered by specialists at other locations through cooperative arrangements (see Chapter 7). The coordinator has the responsibility to see that all evaluation data are properly entered into the GRIN database. These data then become available to all scientists and institutions that have electronic access to the database. Others can obtain hard copy information from the coordinator.

The deposition of good quality seed into NSSL for long term storage is a high priority matter. This should be accomplished as soon as possible after the first seed increase. NSSL has established protocols for number

Fig. 1.11. Pollination-control for seed increases of perennial *Medicago* germplasm. Photo (1988) courtesy R. N. Peaden, USDA-ARS.

of seeds and germination levels for various types of seeds. The rejuvenation of NSSL seedstocks when low in germination or quantity is coordinated with the curator.

Germplasm holdings of the four Regional Plant Introduction Stations (RPIS) as of March 1, 1988 are given in Table 1.8.

Staffing at the RPIS usually includes a Coordinator, Agronomist, Horticulturist, Plant Pathologist, and an Entomologist. These scientists are supported by technicians and clerical workers who may be federal or state employees. The Iowa Station makes effective use of Research Associates who are assigned major responsibilities for handling the maintenance of specific crops plus other phases of the total program. The Georgia Station has separate curators for some of its larger or more

Table 1.8. Plant germplasm accessions maintained at the Regional Plant Introduction Stations as of October 3, 1988.

Station	Total no. of accessions	No. of genera	No. of species	No. of genera with over 500 accessions
Ames, Iowa	26,434	353	1364	11
Griffin, Georgia	58,038	272	1354	20
Geneva, New York	15,130	51	218	9
Pullman, Washington	39,171	232	1729	19

difficult-to-maintain crop species. Students and temporary help are hired at all stations during heavy work periods such as planting, data taking and harvesting operations. The total collection of plant germplasm maintained by these four Regional Stations is steadily increasing. Research is needed to effectively minimize duplications, to form diverse composited populations, and to improve growout techniques to maximize productivity and retention of genetic integrity. Consideration should also be given to the handling of little-used accessions.

Examples of germplasm from RPIS that has contributed to plant improvement and some resultant cultivar releases follow:

Arachis hypogaea—Peanut		
PI 203958	High yield. Good processing and chemical qualities.	'Argentine' is a pure line selection. (Univ. of Georgia 1971)
Crambe abyssinica—Potential new oilseed crop.		
PI 247310	Uniformity, good yield.	'Prophet' (PI 514650) derived by selection
PI 279346	Uniformity, earlier than Prophet.	'Indy'
PI 514649	High yield, intermediate maturity.	'Meyer' derived from PI 279346/PI 247310
Hemarthria altissima—Limpograss		
PI 299993 PI 299994 PI 299995 PI 364888	Productive, high yield, persistant under grazing.	'Redalta' 'Greenalta' 'Bigalta' 'Floralta' 'About 4,900 to 6,000 ha established in South Florida primarily of Bigalta and Floralta
Medicago sativa—Alfalfa		
PI 141462	*Resistance to nematodes and bacterial wilt.*	*'Orunja' from Iran used as a source of nematode resistance, saving growers millions of dollars (Univ. of Georgia 1971)*
Phaseolus vulgaris—Dry bean		
PI 203958	*Fusarium* root rot resistance.	From 1974–1983, used in 11 cultivars of pink, pinto, and red Mexican bean classes (Silbernagel and Hannan 1988)

Pisum sativum—Pea

PI 140295	Resistant to PSbMV and pea enation mosaic virus.	Parent in 'Corvallis' (Dolan and Sherring 1982)

The National Small Grains Collection (NSGC), the largest and most active collection within the NPGS, was moved from Beltsville to the Small Grains Research Center in Aberdeen, Idaho during 1988. The quarantine activity on rice seed imports will be coordinated through the NPGQC at Beltsville. As of October 3, 1988, the NSGC included 111,936 accessions comprised of:

wheat	42,749	rye	2,311
barley	25,743	triticale	1,011
oat	21,342	*Aegilops*	775
rice	17,986		

The collection encompasses 11 genera and 95 species.

The location, main crop genera, and total number of accessions maintained by working collections of seed are given in Table 1.9.

2. National Clonal Germplasm Repositories (NCGR). Plant germplasm that must be maintained vegetatively presents a special challenge to researchers who maintain and use the materials and to administrators who by necessity must allocate funding on a long-term basis. While the Federal Plant Introduction Stations at Glenn Dale, Maryland; Miami, Florida; Savannah, Georgia; and Chico, California served many years as informal repositories for many fruits, nuts, and ornamentals, their capabilities were grossly inadequate to effectively serve the national needs. In 1974 a Workshop of the American Society for Horticultural Science held at Guelph, Ontario dealt with the problem of conservation of fruit and nut tree species. A NPGC report later recommended a network of repositories be established for these clonally propagated crops. Brooks and Barton (1977) described a plan for the establishment of repositories that would meet the maintenance and distribution needs for most vegetatively-propagated fruit and nut species.

Through new budget appropriations to two U.S. Department of Agriculture agencies—the Agricultural Research Service (ARS) and the Cooperative State Research Service (CSRS), plans for construction and staffing of the clonal program were implemented. Because of insufficient funding, the plan that Brooks and Barton described had to be scaled down.

Funding was transferred to ARS in 1986 after a series of attempts to reduce the Special Grant funds within CSRS threatened the existence of stable funding for the activity. ARS during 1987 began the process to Federalize the repositories at Corvallis, Oregon; Davis, California; Hilo,

Table 1.9. Location, and the main crop genera and total number of accessions maintained by working seed collections.

Location	Main genera	Total number of accessions[1]
California, Davis	*Lycopersicon* genetic stocks & species	2,950
Salinas	*Lactuca*, endive, chicory	2,543
Colorado, Ft. Collins	*Hordeum* genetic stocks	3,000
Georgia, Griffin	Bamboo	80
	Abelmoschus, Arachis, Cajanus, Capsicum, Citrullus, Cucurbita, Paspalum, Sesamum, Sorghum, Trifolium (annual), *Vigna, Ipomoea* (true seeds and roots)	58,036
Tifton	*Pennisetum*	5,236
Idaho, Aberdeen	*Aegilops, Avena, Hordum, Oryza, Secale, Triticum,* × *Triticosecale*	111,936
Illinois, Urbana	*Zea* genetic stocks	5,000
	Glycine max	7,939
	G. soja (wild soybean)	867
	G. spp. (perennial soybeans, 12 spp.)	523
Iowa, Ames	*Amaranthus, Beta, Brassica, Cucumis, Cucurbita, Helianthus, Zea*	26,434
Kentucky, Lexington	*Trifolium*	1,500
Mississippi, Stoneville	*Glycine max*	3,364
Missouri, Columbia	*Triticum* genetic stocks	600
New York, Geneva	*Allium, Brassica, Lotus, Lycopersicon, Pisum, Trifolium* (perennial)	15,130
	Pisum genetic stocks	3,000
North Carolina, Oxford	*Nicotiana*	2,000
North Carolina, Raleigh	*Tripsacum* (seed and clonal)	353
North Dakota, Fargo	*Linum usitatissimum*	2,659
Oklahoma, Stillwater	*Arachis*	1,700
South Dakota, Brookings	Native grasses	1,280
Texas, College Station	*Gossypium* spp.	4,770
Utah, Logan	Forage & range grasses	1,410
Washington, Pullman	*Carthamus, Cicer, Eragrostis, Festuca, Lens, Medicago, Phaseolus*	39,171
Wisconsin, Sturgeon Bay	Tuber-bearing *Solanum*	3,834

[1]Most of these numbers are current to October 3, 1988 via data on the GRIN database.

Hawaii; and Riverside, California to ensure funding stability for their activities.

There are now eight repositories as shown in Table 1.10. The primary objectives of these repositories are to collect, identify, preserve, evaluate, and distribute clonal fruit and nut germplasm, and manage the associated information (See Chapter 5). The first formally dedicated

Table 1.10. Clonal repositories of NPGS[1]

Location	Year formalized	Main genera	Accessions
Corvallis, Oregon	1980	*Corylus, Pyrus, Fragaria, Rubus, Vaccinium, Ribes, Mentha, Humulus*	5,815
Davis, California	1981	*Prunus, Juglans, Vitis, Pistacia, Ficus, Olea, Actinidia, Diospyros, Punica, Morus*	3,755
Miami, Florida/ Mayaguez, Puerto Rico	1984	*Manifera, Musa, Persea, Coffea, Saccharum, Theobroma, Anacardium, Bertholettia*	8,116
Geneva, New York	1985	*Malus, Vitis* (American)	3,949
Brownwood, Texas	1984	*Carya, Castanea*	185
Hilo, Hawaii	1986	*Macadamia, Ananas, Psidium, Passiflora, Caricea, Artocarpus*	535
Orlando, Florida	1986	*Citrus*	400
Riverside/Brawley California	1987	*Citrus, Phoenix*	827
National Arboretum Washington, D.C.	pending	Woody ornamental germplasm	

[1]Adapted from Westwood (1986). Most of these data are current to October 3, 1988. Number of accessions change frequently.

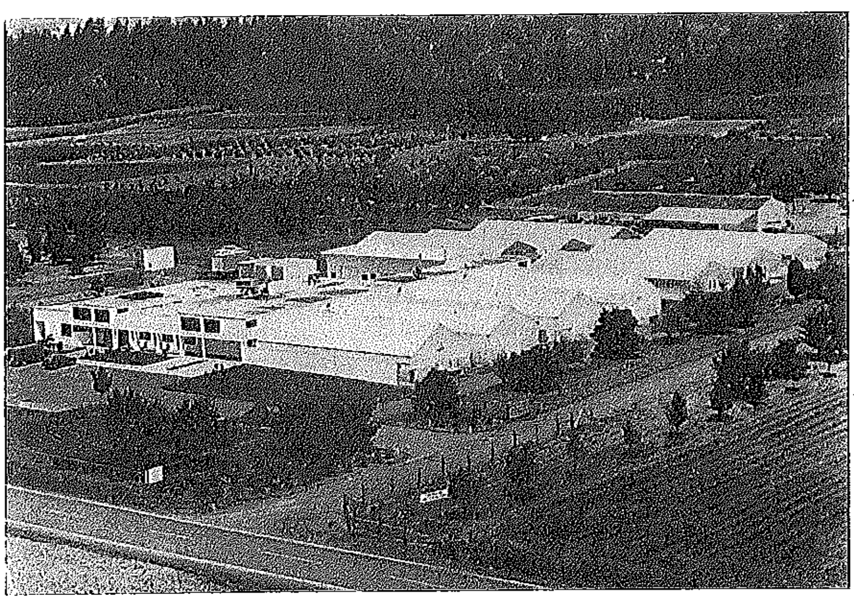


Fig. 1.12. The National Clonal Germplasm Repository at Corvallis, Oregon. (Photo courtesy the Corvallis Respository, 1983).

repository at Corvallis, Oregon became operational in 1980 (Westwood 1986). Its physical layout is shown in Fig. 1.12. The Miami Station has been maintaining and distributing subtropical and tropical fruits and ornamentals since its inception in 1898. The U.S. Plant Introduction Station at Glenn Dale, Maryland, although primarily a quarantine facility, served as an informal repository for many years simply because other facilities did not exist. For example, after the Corvallis and Geneva repositories became functional 268 stocks of pear (*Pyrus* spp.) were moved from Glenn Dale to Corvallis and 692 apple (*Malus*) to Geneva. The Mayaguez Station also has a long history of germplasm maintenance and distribution especially to the southern U.S. and the Caribbean.

While not a formal part of the NPGS clonal repository network, the Interregional Project No. 2 (IR-2) is an important source of commercial virus-free tree fruit germplasm for domestic and foreign research and production programs. This project, which began in 1955, has as its objectives to derive, preserve, and distribute virus-free, deciduous tree fruit germplasm. This project presently maintains almost 1200 accessions consisting of approximately 699 *Prunus*, 294 *Malus*, 163 *Pyrus*, and 8 *Cydonia*. Most of the foreign distributions from IR-2 are made through the PIO.

Westwood (1986) developed a detailed Operations Manual for national clonal germplasm repositories (see also Chapter 5). To increase maintenance efficiency and hold costs to a minimum, innovative methods of germplasm cleanup and retaining pest-free status, long term preservation, rapid propagation, and improved handling for distribution are imperative. Tissue culture, cryopreservation, and other technologies will become increasingly important. A major accomplishment will have been achieved when the clonal materials can be certified virus-free. This will be extremely valuable to U.S. and foreign researchers who use these materials in their crop improvement programs. Also, germplasm becomes more useful and hence more valuable when passport and evaluation information is available in machine-readable form.

Persons involved in carrying out the many tasks associated with the clonal repositories provide a valuable service to U.S. and foreign agriculture and ultimately to the consumer. This program enjoys a high degree of federal, state, private, and international cooperation. Guidance is provided by advisory groups, especially crop advisory and technical committees. Better nutritional quality and a wider range of food crops today and preservation of germplasm to meet the needs of future generations are noble endeavors indeed.

E. Advisory Components and Communications Journal

1. Advisory. NPGS is a highly cooperative program that involves federal, state, and private sectors. With a sizeable funding increase in federal Fiscal Year 1988, the approximate ARS portion of the annual operating budget of NPGS is 26.4 million dollars. With a program of this magnitude, complexity, and diversity, and involving so many locations, advisory groups have become increasingly important in its overall management. These groups provide valuable expertise and guidance pertinent to program functions (White 1985).

Let us now briefly consider these advisory components, their background, composition, and functions.

a. *National Plant Genetic Resources Board (NPGRB)*. The Secretary of Agriculture appoints the members and the Board must be officially renewed every two years (Plant Gen. Res. Board, USDA 1984). The main objectives are (1) to advise the Secretary and the State Agricultural Universities of national plant germplasm needs and (2) to identify high priority programs for conserving and utilizing plant genetic resources. Duties include (1) being aware of activities directed to minimize genetic vulnerability of crops, (2) recommending actions and policies on collection, maintenance, evaluation and utilization of plant genetic resources, (3) recommending actions for improved coordination of domestic and international activities on plant germplasm. (4) recommending policies to improve quarantine and pest monitoring relative to exchange and distribution of germplasm, and (5) advising on new and innovative approaches to plant improvement.

Board members have recognized diverse capabilities and represent federal, state, and private sectors. The Board was a direct outgrowth of recommendations following the southern corn blight epidemic of 1969 and 1970.

b. *National Plant Germplasm Committee (NPGC)*. This committee grew out of the pre-1972 New Crops Coordinating Committee and was tailored to meet the needs of a broadened national program on plant germplasm that resulted from the July 1972 reorganization of ARS.

Representation includes the State Administrative Advisors to the four Regional Projects—NC-7, NE-9, S-9, and W-6 (the Regional Plant Introduction Stations are part of these state/federal projects), selected ARS Area Directors and National Program Staff, CSRS, and private companies. Official observers include representatives from APHIS, Canada, and Mexico.

The committee provides coordination for the research and service of federal, state, and private groups involved with plant germplasm including the development of operational policies, research priorities, long term research programs, and serves as a forum for NPGS.

c. *Plant Germplasm Operations Committee (PGOC).* This committee is a direct outgrowth of the ARS Plant Germplasm Coordinating Committee with expansion to include the National Clonal Germplasm Repositories. It coordinates day-to-day operational activities, reviews and prioritizes plant exploration proposals, identifies problems and needs of the NPGS, and implements, through its members, operational changes and plans for increases, evaluations, and systematic documentation of data.

d. *ARS/NPS Germplasm Matrix Team.* This relatively new group is chaired by the program leader for plant germplasm. Members have, through their staff responsibilities, vested interest in matters dealing with plant germplasm. Specific recommendations are made to the ARS administrator relative to funding of explorations, quarantine problems and procedures, special or emergency funding needs, policy and operational procedures, and other operational and administrative matters.

e. *Technical Advisory Committees (TAC-Regional, Interregional, and Clonal projects).* These committees were established to provide technical guidance, expertise, and assistance in the startup operation of a specific germplasm unit or project and recommend service, budget, and research priorities. In 1988, the TAC for apples and grapes dissolved itself for a job completed, yielding to the associated CACs.

f. *Crop Advisory Committees (CAC).* These committees have evolved over many years. Some emerged from parent groups such as the Tomato Breeders' Round Table, The National Alfalfa Improvement Conference, and the Wheat Improvement Committee. Others, especially those of recent vintage, have been formed because of recognizable germplasm-related needs. Impetus and the need for expanding the CAC network were fueled by the NPGRB's need to know the germplasm status of major crops and by the GRIP and later GRIN Project's need to establish evaluation descriptors for the various crops. These committees represent the germplasm user community for a particular crop or group of crops. They provide expert guidance on germplasm needs, collection gaps, descriptors, documentation, regeneration, evaluation plans, and research needs.

A listing of the committees follows:

- Alfalfa (*Medicago* spp.)
- Apple (*Malus* spp.)
- Barley (*Hordeum* spp.)
- Carya (Pecans, hican, hickories)
- Citrus (orange, grapefruit)
- Clover (*Trifolium* spp., special purpose legumes)
- Cotton (*Gossypium* spp.)
- Crucifer (*Brassica, Raphanus*)
- Grass (forage and turf)
- *Juglans* (walnuts)
- Leafy vegetables (lettuce, spinach)
- Maize (Corn—*Zea* spp.)
- Oat (*Avena* spp.)
- Pea (*Pisum* spp.)

Peanut (*Arachis*)
Pepper (*Capsicum* spp.)
Phaseolus (garden, lima, tepary beans)
Potato (tuber-bearing *Solanum* spp.)
Prunus (peach, plum, almond, cherry)
Pyrus (pear)
Rice (*Oryza* spp.)
Root & Bulb crops (onion, garlic, carrots, beets)
Small fruit (strawberry, raspberry, cranberry, currants)
Sorghum
Soybean (*Glycine* spp.)
Special food legume (lentil; chickpea, faba bean)
Sugarbeet (*Beta*)
Sugarcane (*Saccharum* spp., *Miscanthus* spp., *Erianthus* spp.)
Sunflower (*Helianthus* spp.)
Sweet potato (*Ipomoea* spp.)
Tobacco (*Nicotiana* spp.)
Tomato (*Lycopersicon* spp.)
Tropical fruit and nut (Avocado, *Macadamia*, mango, papaya, others)
Vigna (Southern pea, yardlong bean, others)
Vine crops (squash, pumpkins, cucumber, cantelope)
Vitis (grapes)
Wheat (*Triticum* spp., wild relatives)
Woody landscape plants

g. *Support Organizations.* A number of groups in addition to ARS provide funding, policy-making, local facilities, germplasm increases and/or evaluations, and general program direction. These include CSRS, the Soil Conservation Service, Extension Service, APHIS, State Agricultural Experiment Stations, and private industry.

2. Communications. Until the publication of the quarterly news journal *Diversity* there was no universal or reliable means of communicating news and viewpoints on plant gentic resources. *Diversity* was developed in 1982 after scientists and administrators working in the NPGS expressed a growing need for a news journal to serve the plant genetic resources community both in the United States and abroad. Now established as a respected and authoritative international journal, *Diversity* currently serves readers in the United States, particularly the NPGS community, and in more than 80 other countries.

To ensure the credibility and continuity of the journal, Genetic Resources Communications Systems (GRCS, Inc.) was established in 1984 as a non-profit organization based in Washington, D.C. and became owner and publisher of *Diversity.* A 23-member Board of Directors, comprised of agricultural and environmental leaders from both the public and private sectors, sets and guides policy for GRGS and *Diversity.*

There is general agreement within the NPGS that *Diversity* is emerging as a prominent and important voice for plant germplasm and biological

1.

d[redacted]
g[redacted]
t[redacted]

[redacted]

diversity issues at the national and international level. The journal has gained strong credibility among its readers for its accuracy and objectivity; its breadth of coverage; its selection of topics; its response to changes in format; and overall editorial quality.

Perhaps *Diversity*'s most significant contributions lie in the area of providing a forum for the exchange of ideas, philosophies and information among all levels of programs, organizations, and governments, particularly in the regular reporting of current information about the U.S. National Plant Germplasm System (NPGS), as well as the germplasm activities of the International Agricultural Research Centers (IARC) of the Consultative group on International Agricultural Research (CGIAR).

Diversity's operation depends on contributions from various public and private sector members of the NPGS and the international germplasm community. This support allows for the news journal's relatively modest subscription price as well as for the ability to afford upon request reduced and/or complimentary rates for students and other groups. For information, contact: *Diversity*, 727 8th St. SE, Washington, D.C. 20003, phone (202)543-6843.

IV. NATIONAL AND INTERNATIONAL INTERACTIONS

NPGS has no formal ties with any national or international agencies but has collaborative activities with many. Among those are the Department of Agriculture's Office of International Cooperation and Development (OICD) and the Department of State's Agency for International Development (AID). The group of International Agricultural Research Centers (IARCs) under the oversight of the Consultative Group on International Agricultural Research (CGIAR) mandate carry out germplasm and development programs having broad impact. Funded by FAO, World Bank and specific donor nations, the IARCs have national, regional, and world impact (Hawkes 1985). Although their mandates cover the broad continuum of germplasm and crop development activities, IARC directors have been unable to accomplish everything that has been requested.

Material exchanges with the IARCs bring a close working relationship between them and the NPGS. U.S. programs interact on a scientist and crop by crop basis with the IARCs (Table 1.11). Professional scientific visits, correspondence and exchanges of germplasm make most materials readily accessible. Quarantine restrictions on certain crops make some exchanges impractical for short-term research activities.

Table 1.11. Crop Program in Genetic Resources at International Agricultural Centers[1]

Crop Program	IARCs[2]	Associated NPGS sites
Barley	International Maize and Wheat Improvement Center (CIMMYT) Mexico, D.F., Mexico International Center for Agricultural Research in Dry Areas (ICARDA) Aleppo, Syria	Aberdeen, Idaho
Cassava & yams	Centro Internacional de Agricultura Tropical (CIAT) Cali, Colombia International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria	Griffin, Georgia Mayaguez, Puerto Rico
Chickpea & Pigeonpea	International Crops Research for the Semi-Arid Tropics (ICRISAT) Hyderabad, India	Pullman, Washington Griffin, Georgia
Faba bean & lentils	ICARDA	Pullman, Washington
Forage grasses & legumes	ICARDA, CIAT, International Livestock Centre for Africa (ILCA) Addis Ababa, Ethiopia	Pullman, Washington Logan, Utah RPIS (4)
Maize	CIMMYT	Ames, Iowa
Peanut	ICRISAT, IITA	Griffin, Georgia
Phaseolus beans	CIAT	Pullman, Washington
Potato & sweet potato	International Potato Center (CIP) Lima, Peru IITA, Asian Vegetable Research and Development Center (AVRDC) Tainan, Taiwan	Sturgeon Bay, Wisconsin Griffin, Georgia
Rice	The International Rice Research Institute (IRRI) Manila, Philippines IITA, CIAT	Aberdeen, Idaho
Sorghum & millets	ICRISAT	Griffin, Georgia Tifton, Georgia
Vigna & soya	IITA	Griffin, Georgia Stoneville, Mississippi
Wheat (bread & durum)	CIMMYT, ICARDA	Aberdeen, Idaho

[1]Hawkes 1985

[2]IBPGR, under the CGIAR group activities, deals with these and other crops in collection, preservation, and limited evaluation activities.

CACs attempt to prioritize acquisition of valuable material and address questions relating to time in quarantine and whether the same or similar material is available from other points of origin where the commodity is not quarantined. The Rome-based International Board for Plant Genetic Resources (IBPGR) and the NPGS have many common objectives and much collaborative activity in the areas of plant exploration, conservation, conservation technology, and inventory database, to name a few.

In general, plant exploration and attention to wild species has been left to the International Board for Plant Genetic Resources (IBPGR) whose mandate covers these specific activities. IARCs have limited personnel and have concentrated their expertise while IBPGR can effectively contract these activities to crop experts with appropriate language and ecogeographical knowledge.

IBPGR has sponsored collecting of landraces, primitive cultivars and related wild progenitors of numerous cultivated crops. After appropriate increase of seeds or cuttings, the materials are transferred to one or more of some 37 IBPGR designated base collections. These transfers are handled by the IBPGR Seed Handling Unit at Kew, England and the FAO Seed Laboratory in Rome. IBPGR also assists in multiplying and distributing important existing collections and aids in repatriation activities when material has been lost.

Plucknett and others (1987) stressed the importance of proper preservation of such materials in gene banks to assure availability for research in meeting future food requirements of the world's people.

The NPGS has been identified as a designated base collection site for the following crops: *Abelmoschus, Allium, Amaranthus, Citrus, Cucurbita, Cynodon, Glycine, Ipomoea, Leucaena, Lycopersicon, Oryza sativa, Paspalum, Pennisetum, Phaseolus, Saccharum* (seed and cuttings), *Solanum melongena*, *Sorghum, Triticum, Vigna unguiculata, Zornia*. IBPGR material distributed to a base collection is intended for regeneration and incorporation into a working collection. This is feasibly accomplished with non-prohibited species rather rapidly in the U.S. Prohibited material passing through quarantine measures to assure freedom from infectious agents not yet known in the U.S. takes longer to be made available to scientists. Delays are unavoidable when indexing for viruses in certain fruit and vegetable germplasms. Photoperiod-sensitive crops from tropical areas create special management problems when attempting to regenerate material in the U.S. Winter nurseries in the Caribbean and southern U.S. are often utilized for these growouts. Prohibited *Sorghum* is now being handled in quarantine nurseries at St. Croix, U.S. Virgin Islands.

IBPGR funds research activites involving the development of preservation and propagative techniques for numerous non-seed commodities.

Other research areas include ecogeographic studies, genetic stability in slow growth media and cryopreservation *in vitro* conservation of various vegetatively propagated species, and disease indexing and therapy. Numerous U.S. scientists have been and are involved with such projects. Database management is an increasingly important activity of study, training, and implementation by curators involved with IBPGR-sponsored activities. Uniformity of descriptors, format and medium to facilitate flow and interchange of information are important. In 1986 the database was made available as an online opportunity for the IARCs.

Characterizing and recording highly heritable characters having broadly-based stability are important activities of IBPGR. In 1986, some 42 projects of this nature were sponsored and funded around the world.

The Scientific and Technical Cooperative (STC) program of the USDA Office of International Cooperation and Development (OICD) promotes international cooperation in agriculture and forestry through short-term (1–6 weeks) exchange visits of U.S. and foreign scientists (Off. Intern. Coop & Develop. 1987). OICD-STC also coordinates one to three international workshops/symposia per year on high priority topics of mutual concern to two or more countries. Each year, OICD-STC negotiates a program of activities with each cooperating country based on proposals submitted by U.S. scientists, social scientists, and other specialists from USDA agencies, universities, and private organizations. Proposals are reviewed for potential U.S. benefits, technical merit, and clarity of objectives and work-plan. If proposals are approved by OICD and the foreign government, OICD shares travel, per diem and some miscellaneous costs with participants' sponsoring institutions, and provides administrative support to planning the visit. Co-financing of workshops and symposia is determined on a case-by-case basis. OICD-STC encourages activities which combine participants from USDA, universities and private organizations. Individuals and teams whose proposals are selected are required to submit a detailed report within 60 days of the program's completion.

Participants on exchange visits generally undertake one or more of the following ativities:

- Exchange scientific, statistical and agroeconomic information and data;
- Collect unique resources such as germplasm or biological control organisms, unavailable in the United States;
- Learn about special research, conservation and/or production techniques and/or institutional structures;
- Share new research findings;
- Undertake field work and individual consultations on significant problems facing the U.S. agricultural community;

- Plan future collaborative work.

Exchanges are not intended to cover costs of sabbaticals or to support specialists attendance at international meetings, conferences, or workshops not organized by OICD-STC. The program does not cover participants' salaries. Through OICD, important bilateral efforts have been undertaken with the Soviet Union, the People's Republic of China, and eastern block countries such as Hungary, Poland, and Yugoslavia. Germplasm efforts involving scientists and germplasm exchanges have taken place with each.

Memoranda of Understanding have also been developed to promote germplasm activities. One such memorandum with Mexico was developed by the U.S. National Plant Genetics Resources Board (NPGRB) and the Mexican government's Secretary for Agriculture and Water Development (SARH). Initiatives to collaborate under the provisions of the Memorandum are based on the understanding that both parties are to benefit from the joint activity.

NPGS also cooperates closely with the Soil Conservation Service (SCS) of USDA. SCS personnel are very active in testing domestic and foreign plant materials for potential use in soil and sand dune stabilization, wind breaks, wildlife food and shelter, beautification, and for other purposes. Introductions from abroad are brought in through ARS flow channels. Items, both foreign and domestic, deemed as having sufficient potential for advanced evaluation or formal release are assigned PI numbers and incorporated into NPGS. Valuable additions to NPGS especially of forage species have resulted from these cooperative efforts. ARS and SCS are collaborating in cooperative plant seed regeneration at the Plant Material Centers for RPIS needs.

Training and Collections—Changing technologies have increasingly brought changes to the field of plant breeding. Private industry has assumed more and more of the crop cultivar development activity. Federal elements have appropriately shifted into germplasm-related activities of evaluation and enhancement on those commodities being adequately developed by private industry. Many state universities which have served as the training grounds for breeders for over a half a century have significantly reduced breeding efforts as well as active programs for training breeders. As breeders have retired, there has been not only a loss to the educational and training spectrum but also to the germplasm and breeding collections that have become orphans when program funds were redirected into new areas. One of the common areas into which resources have been redirected became biotechnology, which although untested, is attested to have a great future for crop improvement programs. Biotechnology has the potential of developing useful tools for the breeder and also could become one of the greatest users of plant germplasm as genetic material for unique characters is identified, manipulated and re-incorporated into the same and other species. Certain breeder collections have been recognized as valuable resources to be salvaged and preserved. Scientists with a knowledge of the material are asked to aid in the evaluation and purging of the material since most breeding collections consist of many groups of related lines. Some seed collections have been damaged by poor storage conditions and lack of regeneration during the transition period from the scientist's retirement to the time of realization that the position would not be refilled. Ideally, the retiring breeder should identify the most valuable items in the collection and prioritize as best as possible the material to be preserved.

The NPGS has attempted to recognize important collections through an imprecise "grapevine" in the assemblage of committees throughout the system. Federal units have a clear mandate and collections are generally recognized for their value as a result of the project review process. Less easily accessed are those of minor crops maintained at state institutions where there is little national recognition. Certain genetic stock collections are currently without a clear mandate as to their future. Genetic and cytogenetic stocks became most valuable in helping ascertain genetic linkage maps and evolved further as chemical and radiation mutation studies identified new characters and chromosomal abberations. Breeders have been major contributors to these collections as a result of identifying and creating valuable genetic materials and linkages as they combine useful genetic traits during the breeding process. As more molecular techniques have become available to advance scientific knowledge of the gene, the number of scientific positions available for traditional genetics and breeding has been reduced. Traditional mapping has been deemphasized and has had to share stage with isozyme and restriction fragment length polymorphism (RFLP) maps. Combined maps which integrate the qualitative genetic characters, cytological markers such as translocation breakpoints, and isozyme and RFLP markers, which can possibly be associated with quantitative characters, will greatly enhance the breeder's ability to incorporate and track useful traits leading to improved varieties.

Solutions must be forthcoming not only concerning support for the traditional genetic and cytogenetic stock collections but also for those collections with identified polymorphisms valuable to the biotechnology community. Whereas the cytogenetic collections require painstaking analysis to assure the veracity of a sample, the polymorphism collections require accurate DNA analysis. Each has its unique effort and cost. The NPGS, without a more structured national mandate for these collections, has insufficient funds to support the level of technology required to maintain them properly. These collections represent the ultimate in knowledge about a species—genetically, cytogenetically and chemically—but because of this level of technical knowledge, they are used by only a few specialists who represent a high-cost level of science. Support for these specialized collections competes poorly when limited funds are distributed. The collections, most at state agricultural experiment stations and universities, are not heavily used and this apparent inactivity is a signal to administrators to reduce inputs and place the funds on other activities. This dilemma must be resolved before some of these valuable resources are permanently lost.

V. A LOOK TO THE FUTURE

The NPGS has evolved into an effective, user- and mission-oriented system. It will continue to transform itself over time into a more responsive system through the interrelationships of the operational, advisory, and support organizations. It must continue to respond to short and long term management needs and problems that include financial resource limitations. The NPGS must develop improved methods to identify duplicatory material, to efficiently store and regenerate materials, and to develop a nationwide base of adapted genetic materials for breeders. The strength and future competitiveness of U.S. agriculture are dependent on the successful growth and operation of the NPGS.

The evolution of the NPGS will be directed by focus on user-oriented activities. Although principle activities will involve responsible acquisition and curation of the genetic resources entrusted to it, it will need to be pragmatic enough to identify the future needs of scientists. Research to better characterize and preserve the valuable germplasm is essential. New technologies will enable scientists to literally probe and identify the genes representing the breadth of the diversity which so badly needs to be preserved. Traits associated with each crop's potential genetic vulnerability such as cytoplasmic male sterile sources, vulnerable vertical pathogen resistance, gene transfers of mutable traits, etc. must be identified. Breeders involved in pre-breeding activities must provide a diverse assortment of practical materials for commercial and public breeders that will minimize a regions genetic risk. Seed research to understand the physiology of viability to minimize storage losses must continue until maximim practical efficiency in storage is attained. Quarantine research to identify and eliminate diseases in germplasm caused by viruses, mycoplasms, and presently unidentified entities needs to be conducted to identify exotic pathogens and ensure the plant health of U.S. agriculture. Information systems such as GRIN must develop to accomodate the increasingly complex user demands in a rapidly changing technological world.

The NPGS will be increasingly affected by the international issues involving germplasm, environmental issues, and patents and laws affecting the use, distribution, and ownership of germplasm. The international community must be prepared to recognize the principle of reciprocity of exchange under which the NPGS operates. The USDA and NPGS make all material freely available for research on a worldwide basis. Patent laws will not necessarily restrict the distribution but may affect the short term utilization of patented germplasm. In general, patented material is not held in the NPGS unless there is concern that the material may be lost.

Users of germplasm must respond with a greater sense of responsibility to preserve that which is useful. The private industry must help identify materials containing valuable traits no longer considered critically proprietary by the various companies and provide them to NPGS for safeguarding for the future. Identification of what characterizes useful traits and genetic diversity is essential. Research in this area is difficult and often subjective but answers will play an important role in future germplasm management.

LITERATURE CITED

Adair, C. R., J. H. Martin, T. H. Johnston. et. al. 1975. A summary of rice production investigations in USDA, 1898–1972. *Rice J.* **78**(4):24–26.

Agricultural Research Service-USDA. 1974. *Gossypium* germplasm. *USDA-ARS-H-2.*

Agricultural Research Service-USDA. 1987. The germplasm resources information network—GRIN, a brief history and introduction. *Report by Data Management Unit,* Plant Genetics and Germplasm Institute.

Animal and Plant Health Inspection Service-USDA. 1982. Foreign quarantine notices, **Part 319**:1–27. Title 7-Agriculture, Chapter III.

Bamberg, J. and R. E. Hanneman, Jr. 1987. Special report to IR-1 Technical Committee Meeting, Sept. 28, 1987 (Processed report).

Bernard, R. L. 1983. Content and utilization of the national soybean germplasm collection. *Proc. 13th Soybean Seed Research Conf.* p. 29–39.

Bernard, R. L., G. A. Juvik, and R. L. Nelson. 1987. USDA soybean germplasm collection inventory. *INTSOY Series 30.*

Bernard, R. L. and G. A. Juvik. 1988. USDA Northern Soybean Germplasm Collection Report. *Soybean Gen. Newsletter* **15**:9–12.

Brooks, H. J. and D. W. Barton. 1977. A plan for national fruit and nut germplasm repositories. *HortScience* **12**:298–300.

Cunningham, Isabel S. 1984. Frank N. Meyer—plant hunter in Asia. Iowa State University Press, Ames.

Cunningham, Isabel S. 1987. Howard Scott Gentry: agriculture's renaissance man. *Diversity* **11**:23–24.

Dillman, A. C. 1953. Classification of flax varieties, 1946. *USDA Tech. Bull. 1064.*

Dolan, D. D. and W. R. Sherring. 1982. Progress in the evaluation and use of plant germplasm in the Northeast, 1974–1979. *Special Report 43.* New York State Agr. Expt. Sta., Geneva.

Fryxell, P. A. 1985. Taxonomy and germplasm resources. p. 27–57. In: Cotton. *ASA Monogr. 24.* Amer. Soc. Agronomy, Madison, WI.

Hanneman, R., Jr., and R. W. Ross. 1978. Inter-regional potato project IR-1. *Univ. of Wisconsin Exp. Station Publication.*

Hawkes, J. G. 1985. Plant genetic resources. The impact of the International Agricultural Research Centers. *CGIAR Study Paper 3.*

Holm, L., J. V. Pancho, J. P. Herberger, and D. L. Plucknett. 1979. A geographical atlas of world weeds. John Wiley & Sons, New York.

Hyland, H. L. 1977. History of U.S. Plant Introduction. *Environ. Rev. J.* Issue **4:**26–33.

Kăhn, R. P. 1983. Safeguards and the international exchange of plant germplasm as seeds. *Seed Sci. & Technol.* **11:**1159–1173.

Kaiser, W. J. 1983. Plant introduction and related seed pathology research in the United States. *Seed Sci. & Technol.* **11:**1197–1212.

Kaiser, W. J. 1987. Testing and production of healthy plant germplasm. *Tech. Bull. 2.*, Danish Govt. Institute of Seed Pathology for Developing Countries, Copenhagen, Denmark.

Moseman, J. G. and D. H. Smith, Jr. 1985. Germplasm resources. p. 57–71. In: Barley. *ASA Monogr. 26.* Amer. Soc. Agronomy, Madison, WI.

Natl. Plant Genetic Res. Board-USDA. 1979. Plant genetic resources: conservation and use.

Natl. Plant Genetic Res. Board-USDA. 1984. Plant germplasm conservation and use.

Office of Intl. Coop. and Develop.-USDA. 1987. Scientific and technical cooperation program. OICD-STC.

Parliman, B. J. and G. A. White. 1985. The plant introduction and quarantine system of the United States. *Plant Breed. Rev.* **3:**361–434.

Percival, A. E. 1987. The national collection of *Gossypium* germplasm. *So. Coop. Series Bull. 321.*

Perry, M. C. 1988. The Germplasm Resources Information Network (GRIN)—a genetic resources information management system for the United States. *IBPGR Newsletter 73* (in press).

Perry, M., A. K. Stoner and J. D. Mowder. 1988. A plant germplasm information management system: Germplasm Resources Information Network. *HortScience* **23:**57–60.

Plucknett, D. L., N. J. H. Smith, J. T. Williams, and N. M. Anishetty. 1987. Gene Banks and the World's Food. Princeton Univ. Press, Princeton, NJ.

Reitz, L. P. 1976. Improving germplasm resources. p. 85–97. In: Barley. *ASA Monogr. 26.* Amer. Soc. Agronomy, Madison, WI.

Sharp, W. C., G. A. White, and J. A. Briggs. 1987. The plants that followed people. p. 54–58. In: W. Whyte (ed.), USDA Yearbook of Agriculture.

Silbernagel, M. J. and R. M. Hannan. 1988. Utilization of genetic resources in the development of commercial bean cultivars in the U.S.A. In: P. Gepts (ed.), Genetic resources, domestication, and evolution of *Phaseolus* beans. Kluwer Ac Publications, The Netherlands.

Skrdla, W. H. 1975. The U.S. Plant Introduction System. *HortScience* **10:**570–574.

Terrell, E. E., S. R. Hill, J. H. Wiersema, and W. E. Rice. 1986. A checklist of names for 3,000 vascular plants of economic importance. *USDA Agriculture Handb. 505.*

Univ. of Georgia. 1971. The national program for conservation of crop germplasm. Univ. Printing Dept., Univ. of Georgia, Athens.

Waterworth, H. E. and G. A. White. 1982. Plant introductions and quarantine: the need for both. *Plant Dis.* **66:**87–90.

Westwood, M. N. 1986. Operations Manual for National Clonal Germplasm Repositories. Processed report. USDA-ARs and Oregon State Univ.

White, George A. 1985. The national plant germplasm system of the United States. p. 61–

66. *Proc. of the Inter. Sym. on South East Asian Plant Genetic Resources.* Lembaga Biologi Nasional-LIPI, Jakarta, Indonesia.
White, George A. 1987. Plant introduction and quarantine: a marriage of necessity. p. 116–125. *Anales Simposio Recursos Fitogenetico (1984)*, UACH-IBPGR, Valdivia, Chile.
White, G. A., S. A. Eberhart, P. A. Miller, and J. D. Mowder. 1988. Plant materials registered by Crop Science incorporated into NPGS. *Crop Sci.* **28**:716–717.
Wilkes, G. 1985. Current status of crop plant germplasm. In: CRC Critical Reviews in Plant Science, Vol. **1**(2):133–181.