Crop Germplasm Conservation and Developing Countries

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Summary. Loss of the genetic diversity of some of the world's crops has accelerated in recent decades, with many crops becoming increasingly susceptible to diseases, pests, and environmental stresses. A global network of gene banks has therefore been established to provide plant breeders with the genetic resources necessary for developing more resistant crops that will enable farmers to maintain high yields. Most of these gene banks now store the germplasm of only the major crops such as cereals, potatoes, and grain legumes. Cultivated varieties of these crops are conserved as well as wild species that might otherwise become extinct. Tropical cash crops such as bananas and coconuts are also important food crops in many Third World countries, and more effort needs to be made to conserve the germplasm of these crops as well as of other important plants such as plantation crops, medicinal herbs, and fruit and timber trees.

While crop yields have been generally increasing, the genetic base of most of the important food crops has been rapidly narrowing (*1*). The adoption of high-yielding varieties over broad areas has resulted in subsistence farmers abandoning their traditional varieties that were rich in genetic diversity. Since World War II, for example, 95 percent of Greece's wheat varieties have been abandoned and virtually all of the sorghum races of South Africa disappeared after the introduction of high-yielding Texas hybrids (*2*).

When vast areas are planted to a single crop variety, agricultural productivity can become vulnerable to factors that limit yields (*3*). In 1846, the late blight fungus *Phytophthora infestans* cut Ireland's potato production in half and triggered a mass emigration; the country's basic staple was vulnerable because it was derived from only a handful of introductions. The susceptibility of a parental line of hybrid maize to the fungus *Helminthosporium maydis* caused an average 15 percent reduction of U.S. corn yields in 1970 and cost farmers hundreds of millions of dollars in lost production. In the Soviet Union, the Bezostaja wheat variety spread outside its original area of cultivation during a period of relatively mild winters. By 1972 the variety covered 15 million hectares, but a return of cold weather that year resulted in the loss of millions of tons of winter wheat (*4*).

Gene Banks

To counteract the genetic vulnerability of crops, agronomists and plant genetecists have made collections of germplasm so that plant breeders will have the genetic resources necessary for developing plants that will be resistant to diseases, pests, poor soils, and harsh weather.

Until the 1960's, most of these germplasm collections were held by the developed nations which financed explorations for varieties of cultivated crops, particularly the major cereals, and their wild relatives. In many temperate zone countries, promising plants were gathered both at home and in the tropics and were usually assembled in botanical gardens, such as Kew Gardens in London. Plants were maintained in open plots, in glasshouses and, to a lesser extent, as seeds. The technology for storing crop germplasm under refrigeration was not developed until the late 1920's. The Soviet Union gained an early lead in collecting and conserving plant genetic resources as a result of the work of V. I. Vavilov, who set up the All-Union Institute of Plant Industry (VIR) in the 1920's, but long-term storage facilities for germplasm were not established in the U.S.S.R. until the 1970's. The United States has collected and evaluated crop germplasm since the last century, but did not establish its first center for the conservation of crop germplasm, the Regional Plant Introduction Station in Ames, Iowa, until 1947. The first national facility for the cold preservation of seed crops, the National Seed Storage Laboratory (NSSL) operated by the U.S. Department of Agriculture, was built at Fort Collins, Colorado, in 1958 (*5*). Germplasm collections in Western Europe, Canada, and Australia are generally smaller and less comprehensive than those of the United States and the Soviet Union.

In the 1960's it became apparent that more collecting and preservation were needed for the genetic resources of tropical and subtropical crops. The Food and Agricultural Organization of the United Nations (FAO) therefore spearheaded an effort to bring the issue of germplasm conservation to the attention of the world community. In 1961, FAO organized the first international technical meeting on plant exploration and introduction, and a panel of experts was established 4 years later. Participants at two conferences on crop genetic resources, in 1967 and 1973, recommended that a global network of crop gene banks be established. In 1972 the U.N. Conference on the Human Environment adopted a resolution calling for an international program to preserve the germplasm of tropical crops. In the same year, the Consultative Group on International Agricultural Research (CGIAR) convened a working group at Beltsville, Maryland, which urged the creation of a network of nine regional genetic resource centers and a series of institutions, consisting mostly of International Agricultural Research Centers (IARC's), for the collection of genetic material of specific crops. The International Board for Plant Genetic Resources (IBPGR), with headquarters at FAO in Rome, was established in 1974 as an outgrowth of CGIAR involvement in this effort.

The increasing concern for the conservation of crop genetic resources spurred some concrete action. In 1975, an IBPGR survey revealed that only eight

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Table 1. Wheat (*Triticum* species) accessions in gene banks (*7*).

Accessions	Term of storage	Institution	Location
63,000	Medium, long	VIR*	Leningrad, U.S.S.R.
50,000	Medium	CIMMYT	El Batán, Mexico
46,186	Long	NSSL*	Fort Collins, United States
36,710	Medium	USDA National Small Grains Collection	Beltsville, United States
31,000	Short	ARO	Bet Dagan, Israel
26,000	Medium, long	Instituto del Germoplasma*	Bari, Italy
20,200	Long	New South Wales Department of Agriculture	Tamworth, Australia
20,000	Short†	CGI	Beijing, China
17,000	Short	ICARDA	Aleppo, Syria
13,600	Short†	IPIGR	Plovdiv, Bulgaria
10,000	Medium, long	Zentralinstitut für Genetik und Kulturpflanzenforschung	Gatersleben, Democratic Republic of Germany

*IBPGR-designated base collections. †Long-term facility being constructed.

institutions in the world had facilities for the long-term storage of seeds; 7 years later the total had reached 33. By 1985, the less-developed countries are expected to overtake the industrial nations in the number of gene banks with long-term storage capacity (Fig. 1).

Despite its small staff of six scientists at headquarters, two in Washington, and a modest annual operating budget of under U.S.$4 million, IBPGR has played a central part in stimulating the development of germplasm storage facilities in the Third World. The board now employs five regional officers for Southwest and Central Asia (stationed at Aleppo, Syria), Southeast Asia (Bangkok), Western Africa (Upper Volta), East Africa (Nairobi), and Latin America (Cali, Colombia). IBPGR supports missions to collect plant germplasm, helps upgrade gene banks, improves documentation, and strengthens training programs. It also provides funds for initiating germplasm work; IBPGR-sponsored activities now span over 80 countries and involve more than 120 species, 50 of them crops.

IBPGR has not acted as the sole catalyst for gene bank construction and germplasm evaluation in developing countries. The Federal Republic of Germany has helped to establish two regional long-term storage facilities at the Plant Genetic Resources Center (PGRC) in Addis Ababa, Ethiopia, and at CATIE (Centro Agronomico Tropical de Investigación y Enseñanza) near Turrialba, Costa Rica. The Inter-American Development Bank has assisted Brazil in launching its genetic resources program within EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária). New or additional storage facilities are planned or under construction in Thailand (with financial support from Japan and IBPGR), Pakistan (World Bank), India (United Kingdom), the People's Republic of China (Rockefeller Foundation), Bangladesh (IBPGR, Asian Development Bank), and Bulgaria (U.N. Development Bank). Other organizations that have assisted germplasm conservation efforts include FAO, the U.N. Environment Program, the Ford Foundation, and the governments of Australia, Japan, Sweden, and the United States. Approximately U.S.$55 million was spent worldwide on plant genetic resource activities in 1982 (*6*).

Principles and Operation of Gene Banks

Three principles guide the collection, conservation, and exchange of germplasm. First, when an accession is gathered a sample is left in the country of origin for national use. Second, germplasm is made freely available to all bona fide workers; and third, all long-term collections are duplicated and maintained in another location.

To be useful to plant breeders, a gene bank must have information that is easily retrieved and understood about the material in stock. The first step in banking the germplasm is the compilation of a checklist of the plant's characters and the environment in which it grows. Field data are, ideally, entered later into a computer. Before being placed in cold storage, the sample is often multiplied so that there will be sufficient seeds or vegetative materials for storage and to send to other institutions. The next step is the evaluation of the plant by specialists in such fields as pathology, entomology, plant physiology, and agronomy.

Germplasm of crops grown from true seed is stored in three main types of

Table 2. Rice (*Oryza* species) accessions in gene banks (*7*).

Species	Accessions	Term of storage	Institution	Location
Common rice (*O. sativa*)	60,000	Medium, long	IRRI*	Los Baños, Philippines
	30,000	Medium	IARI	New Delhi, India
	18,065	Long	NSSL*	Fort Collins, United States
	18,000	Medium, long	NIAS*	Tsukuba, Japan
	15,249	Medium	CRRI	Cuttack, India
	11,230	Short	Agricultural Research Center	Beltsville, United States
	8,226	Medium	WARDA	Monrovia, Liberia
	6,000	Medium	Central Research Institute for Agriculture	Bogor, Indonesia
	5,100	Medium	Bangladesh Rice Research Institute	Dacca, Bangladesh
	4,600	Medium, long	Koitotron Seed Bank	Penang, Malaysia
	4,227	Medium, long	Agricultural Experiment Station	Suweon, Korea
	4,000	Short	Bangkhen Rice Station	Bangkok, Thailand
	3,765	Medium†	IITA*	Ibadan, Nigeria
	3,500	Medium, long	VIR	Leningrad, U.S.S.R.
	3,200	Short	INTA	Cordoba, Argentina
African rice (*O. glaberrima*)	2,575	Medium, long	IRRI*	Los Baños, Philippines
	1,515	Medium	IITA*	Ibadan, Nigeria

*IBPGR-designated base collections. †Long-term facility about to be operational.

banks. In long-term gene banks, known as base collections, samples are stored at −10° to −20°C for several decades or potentially up to a century in some cases. In medium-term facilities, seeds are maintained at 0° to 5°C for up to 20 years. In short-term collections, germplasm is kept at ambient temperatures or under refrigeration above 5°C. Under such conditions seeds may last a few years. In all three types of collections, the moisture content of seeds is usually lowered before storage. Medium- and short-term facilities are referred to as active or working collections; samples are constantly withdrawn for evaluation and breeding purposes. Germplasm in base collections is rarely disturbed.

Germplasm of vegetatively propagated crops is difficult to maintain and usually must be grown continuously or replanted frequently; gene banks housing such germplasm are particularly susceptible to natural disasters and political change. For these reasons, some tropical crops have not been adequately collected or maintained.

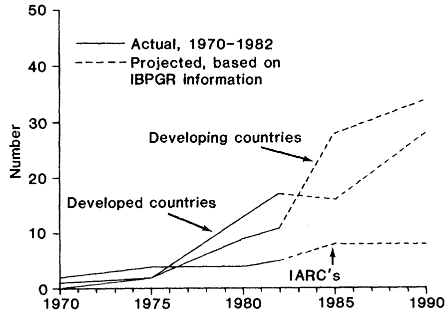

Fig. 1. The number of gene banks for long-term storage of crop germplasm that were in operation between 1970 and 1982 and are projected to be in operation by 1990 (6).

Status of Germplasm Collections

Cereals account for most of the accessions in gene banks. The size of a collection, though, is not necessarily commensurate with its value; its usefulness in serving present and future breeding programs is the crucial issue. Nevertheless, the number of accessions in a gene bank provides a rough measure of its activity and of the relative importance attributed to particular crops. Wheat accounts for over 400,000 entries in gene banks, with facilities for the long-term storage of wheat germplasm being concentrated in the industrial nations (Table 1) (7). In the Third World, the largest wheat gene banks are found at CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo) near Mexico City, and at ICARDA (International Center for Agricultural Research in the Dry Areas) at Aleppo, Syria. CIMMYT maintains a medium-term collection of 50,000 tropical and subtropical wheats and triticale (a cross between wheat and rye), while ICARDA holds some 17,000 wheat samples. Wheat breeders throughout the world still rely heavily on the small grains collection at Beltsville and on the NSSL for material.

With about 200,000 accessions, collections of rice germplasm are not as large as those of wheat. Seven of the ten largest rice gene banks are in developing countries (Table 2).

Since its inception in 1962, IRRI has assembled the world's largest rice gene bank. The center's rice collection is especially useful because of the care taken to record information about samples. Each entry is checked for 45 morphological and agronomic qualities. Fresh seeds are prepared for short-, medium-, and sometimes long-term storage, while duplicates are sent to NSSL. The computerized germplasm information base is being expanded to handle an expected 125,000 accessions by 1985. The rice gene bank at IITA in Ibadan, Nigeria, concentrates on upland varieties which are held in medium-term storage; a long-term storage facility became operational in 1982. IITA, with inputs from IBPGR, is also collecting an African domesticated rice, *Oryza glaberrima*, a task shared by IRRI (Table 2). IITA assists WARDA in its germplasm work which concentrates on assembling African paddy rices.

Much remains to be done with the conservation of other tropical cereals. Only two long-term gene banks for maize are located in the Third World, one in Argentina and the other (not shown) in the Philippines (Table 3). The University of Illinois serves as a repository of maize mutants and holds more than 100,000 samples for use by the world research community (8). In the Third World, CIMMYT and Mexico's national program, INIA (Instituto Nacional de Investigaciónes Agrícolas), have the largest short-term collections of maize. The CIMMYT maize gene bank contains entries from over 50 countries. Domesticated maize comprises most of CIMMYT's working collection, but wild relatives such as annual teosinte (*Zea mexicana*) and the recently discovered perennial maize (*Z. diploperennis*) are also included.

Sorghum (*Sorghum bicolor*) is poorly represented in gene banks. The PGRC in Ethiopia is the only facility in the Third World for long-term storage of sorghum germplasm, and NSSL and VIR are the only other long-term gene banks for the cereal (Table 4). The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has the largest collection with 24,000 samples from 68 countries kept in a medium-term gene bank. With help from the Japanese government and the Asian Development Bank, ICRISAT expects to complete construction of a long-term facility in 1983. ICRISAT's sorghum accessions have increased markedly since 1978 when there were 15,000 entries (9), but many landraces have not been collected.

Barley (*Hordeum vulgare*) is relatively well represented in gene banks, but collections are held mostly in the developed world (Table 5). In the industrial nations, barley is used mostly by brewers and as an animal feed, but in tropical highlands and in the drier portions of the subtropics the cereal is used as a food for humans. The CNPT (Centro Nacional de Pesquisa de Trigo) in Brazil, ICARDA, and CIMMYT hold the largest barley germplasm collections in the Third World. Some barleys tolerate drought and frost and can be used in wide crosses with other cereals, such as wheat. Many landraces of tropical highlands and wild species remain to be collected.

Table 3. Corn (*Zea mays*) accessions in gene banks (7).

Accessions	Term of storage	Institution	Location
15,084	Medium, long	VIR*	Leningrad, U.S.S.R.
15,000	Medium	Institute of Maize Research	Belgrade, Yugoslavia
14,000	Short, medium	CIMMYT	El Batán, Mexico
11,000	Short, medium	INIA	Mexico City, Mexico
7,619	Long	NSSL*	Fort Collins, United States
5,006	Short	ICA	Colombia
3,444	Medium	Universidad Nacional Agraria La Molina	Lima, Peru
3,200	Short	Research Institute for Cereals and Technical Plants	Fundulea, Romania
3,000	Medium, long	INTA	Pergamino, Argentina

*IBPGR-designated base collections.

Table 4. Sorghum (*Sorghum bicolor*) accessions in gene banks (*7*).

Accessions	Storage	Institution	Location
24,000	Medium*	ICRISAT†	Hyderabad, India
14,000	Long	NSSL†	Fort Collins, United States
9,815	Short	USDA/SEA-AR	Experiment, Georgia, United States
9,615	Medium, long	VIR	Leningrad, U.S.S.R.
5,000	Medium, long	PGRC†	Addis Ababa, Ethiopia
4,900	Short	Research Institute for Cereals and Technical Plants	Fundulea, Romania
4,610	Short	Sugar Crops Field Station	Meridian, United States
4,000	Short	Mayaguez Institute of Tropical Agriculture	Mayaguez, Puerto Rico
4,000	Short	American Sorghum Project	Tihama, Yemen

*Long-term facility under construction. †IBPGR-designated base collection.

The millets, comprising some dozen species in six genera, seldom enter world trade but they are nevertheless a valuable food for humans in arid portions of Africa, Asia, and the Mediterranean region. Millets thrive in diverse problem environments, including areas with poor soils or subject to drought, hence their importance in the Third World. Only a handful of gene banks preserve millet germplasm (Table 6) and only one institution, ICRISAT, has facilities near completion for long-term storage of these cereals. Pearl millet (*Pennisetum typhoides*) is the best represented of the millets in gene banks; however, entries of other millets total less than 20,000 in all gene banks.

Tuber crops are generally poorly represented in gene banks. The common potato (*Solanum tuberosum*), with 44,000 accessions, is the best collected root crop (Table 7). The International Potato Center (CIP) in Peru holds close to a third of the world potato germplasm collection. Of the 13,000 potato accessions maintained there, 6000 are clones that are grown each year near Huancayo in the Andes. Duplicates are sent to CIP's headquarters in Lima and to ICA (Instituto Colombiano Agropecuario), Colombia's national agricultural research institution. Peru, the home of potato, accounts for 82 percent of CIP's accessions (*10*). About 80 percent of CIP's collection is *S. tuberosum*, but more restricted domesticates, such as *S. ajanhuiri* and *S. stenotomum*, are also represented (*11*). CIP sends duplicates of wild potato seeds to the Inter-Regional Potato Introduction Station in Wisconsin which houses the largest collection of wild potato seeds with over 90 species represented (*12*).

By means of tissue culture techniques, it is now possible to store potato plants in test tubes. Growth in vitro can be slowed by cool temperatures and the use of certain culture media; at 6° to 10°C potato plantlets survive 2 years. This method saves space and money since the material does not have to be planted in fields every year. The germplasm of cassava and sweet potato is also now stored in test tubes. Yams (*Dioscorea* species), taro (*Colocasia esculenta*), cocoyams (*Xanthosoma* species), and ullucu (*Ullu-*

Table 5. Barley (*Hordeum* species) accessions in gene banks (*7*).

Accessions	Term of storage	Institution	Location
25,284	Long	NSSL	Fort Collins, United States
23,371	Medium	Agricultural Research Station	Beltsville, United States
21,000	Long	Plant Gene Resources Office*	Ottawa, Canada
19,500	Short	CNPT	Passo Fundo, Brazil
17,459	Medium, long	VIR	Leningrad, U.S.S.R.
13,900	Long	Nordic Gene Bank*	Lund, Sweden
13,000	Medium	ICARDA	Aleppo, Syria
10,200	Medium, long	Zentralinstitut für Genetik und Kulturpflanzenforschung	Gatersleben, Democratic Republic of Germany
10,000	Short	CIMMYT	El Batán, Mexico
6,025	Medium	Barley Germplasm Center	Kurashiki, Japan
5,263	Medium, long	NIAS*	Tsukuba, Japan
5,017	Medium, long	FAL	Braunschweig, Federal Republic of Germany
5,000	Medium, long	PGRC	Addis Ababa, Ethiopia

*IBPGR-designated base collections.

Table 6. Millet accessions in gene banks (*7*).

Species	Accessions	Term of storage	Institution	Location
Pearl millet (*Pennisetum typhoides*)	14,340	Medium*	ICRISAT†	Hyderabad, India
	2,247	Short	AICMIP	Poona, India
	2,100	Medium	ORSTOM	Bondy, France
	1,200	Long	Plant Gene Resources Office†	Ottawa, Canada
	1,000	Long	NSSL†	Fort Collins, United States
Foxtail millet (*Setaria italica*)	5,017	Short	AICMIP	India
	3,226	Short	CGI	Beijing, China
	1,160	Medium*	ICRISAT†	Hyderabad, India
Finger millet (*Eleusine coracana*)	5,904	Short	AICMIP	India
	1,241	Medium*	ICRISAT†	Hyderabad, India
Kodo millet (*Paspalum scrobiculatum*)	1,405	Short	AICMIP	Poona, India

*Long-term facility under construction. †IBPGR-designated base collections.

Table 7. Root and tuber crop accessions in gene banks (7).

Species	Accessions	Storage	Institution	Location
Potato (*Solanum* species)	13,000	Medium, long	CIP*	Lima, Peru
	9,435	Medium, long	VIR	Leningrad, U.S.S.R.
	6,000	Medium	SPBS	Roslin, United Kingdom
	5,000	Short, medium	EMBRAPA	Brasilia, Brazil
	3,400	Short	INIPA	Peru
	2,800	Medium	Inter-Regional Potato Introduction Station	Sturgeon Bay, United States
	2,370	Short, medium	FAL	Braunschweig, Federal Republic of Germany
Sweet potato (*Ipomoea batatas*)	1,250	Short	USDA/SEA-AR	Charleston, United States
	1,200	Short	Lembaga Pusat Penelitian Pertanian	Bogor, Indonesia
	1,200	Short	Kyushu National Agricultural Experiment Station	Kagoshima, Japan
	1,000	Short	AVRDC	Shanhua, Taiwan
Cassava (*Manihot esculenta*)	3,000	Medium	CIAT	Cali, Colombia
	2,922	Medium	IITA	Ibadan, Nigeria
	1,800	Short	Central Tuber Crops Research Institute	Kerala, India
	1,500	Short	CENARGEN	Brazil
	1,060	Short	National Cassava Center	Umuahia, Nigeria
Yams (*Dioscorea* species)	7,100	Short	Dodo Creek Research Station	Honiara, Solomon Islands

*IBPGR-designated base collection.

Table 8. Accessions of grain legumes in gene banks (7).

Species	Accessions	Term of storage	Institution	Location
Soybean (*Glycine max*)	10,000	Medium	AVRDC	Shanhua, Taiwan
	8,350	Long	NSSL	Fort Collins, United States
	3,000	Medium, long	VIR	Leningrad, U.S.S.R.
	3,000	Medium	NIAS	Tsukuba, Japan
	3,000	Short	Oil Bearing Crops Institute	Wuhan, China
	2,900	Short	Shadong Agricultural Academy	Jinan, China
Common bean (*Phaseolus vulgaris*)	28,750	Medium, long	CIAT*	Cali, Colombia
	7,979	Short	USDA/SEA-AR	Pullman, United States
	4,250	Medium	University of Cambridge	Cambridge, United Kingdom
	4,193	Long	NSSL	Fort Collins, United States
	3,109	Short	ICA	Colombia
	2,627	Short	Research Center for Agrobotany	Tapioszele, Hungary
	2,575	Short	USDA/SEA-AR	Geneva, Georgia
	2,000	Short	Nairobi University	Kenya
	2,000	Short	University of Malawi	Lilongwe, Malawi
Lima bean (*Phaseolus lunatus*)	2,300	Medium	CIAT*	Cali, Colombia
Runner bean (*Phaseolus coccineus*)	1,000	Medium	CIAT*	Cali, Colombia
Phaseolus species	1,000	Long	NVRS	Wellesbourne, United Kingdom
Mungbean (*Phaseolus aureus*)	5,000	Medium	AVRDC	Shanhua, Taiwan
	3,000	Short	Punjab Agricultural University	Ludhiana, India
	2,500	Short	University of the Philippines	Los Baños, Philippines
	2,100	Short	University of Missouri	Columbia, Missouri
	1,000	Short	IARI	Delhi, India
Cowpea (*Vigna unguiculata*)	12,000	Medium	IITA*	Ibadan, Nigeria
	3,518	Short	USDA/SEA-AR	Experiment, Georgia, United States
	1,050	Medium	VIR	Leningrad, U.S.S.R.
	1,000	Medium	National Plant Genetic Laboratory	Los Baños, Philippines
Bambara ground nut (*Voandzeia subterranea*)	2,000	Medium	IITA	Ibadan, Nigeria
Chickpea (*Cicer arietinum*)	13,000	Medium†	ICRISAT*	Hyderabad, India
	4,500	Short‡	ICARDA	Aleppo, Syria
	3,100	Short	USDA/SEA-AR	Pullman, United States
	1,685	Medium	VIR	Leningrad, U.S.S.R.
	1,600	Medium	INIA	Mexico City, Mexico
Pigeonpea (*Cajanus cajan*)	8,850	Medium	ICRISAT*	Hyderabad, India
Ground nut (*Arachis hypogaea*)	8,800	Medium	ICRISAT	Hyderabad, India
	4,685	Short	USDA/SEA-AR	Experiment, Georgia, United States
	3,925	Long	NSSL	Fort Collins, United States
	2,500	Medium	IITA	Ibadan, Nigeria
	1,053	Medium, long	VIR	Leningrad, U.S.S.R.
Lentil (*Lens esculenta*)	5,400	Long¶	ICARDA	Aleppo, Syria
Faba bean (*Vicia faba*)	5,000	Short‡	ICARDA	Aleppo, Syria
Lupin (*Lupinus mutabilis*)	3,342	Short	INIPA	Peru
Winged bean (*Psophocarpus tetragonolobus*)	1,000	Short	NBPGR	New Delhi, India
	1,000	Long	TISTR*†	Bangkok, Thailand
	400	Long	IPB*†	Los Baños, Philippines

*IBPGR-designated base collections. †Long-term facility under development. ‡Medium-term facility under construction. ¶In deep-freeze cabinets.

cus tuberosus) are represented sparingly in gene banks.

The germplasm conservation picture for legumes is much brighter than for root crops. At least 14 species of grain legumes, ranging from the commercially important soybean (*Glycine max*) to a little-known Andean lupin (*Lupinus mutabilis*), are deposited in gene banks (Table 8). Unlike the situation with most cereals, the majority of grain legume gene banks are in the Third World.

Gene Banks and Breeding

Scientists screen germplasm for resistance to insect and disease attack and for tolerance to poor soils and climatic extremes. Whenever possible, breeders attempt to introduce resistance to a broad range of diseases and pests into a crop so that yields will be more stable. Also, gains are likely to be longer lasting if more than one gene coding for resistance or tolerance can be transferred successfully to a variety. Gene banks are more useful when collections have been evaluated and documented.

A high priority for plant breeders is the development of resistance to crop diseases, and screening for these traits accounts for a substantial amount of time and resources of breeders. In India, the Indian Agricultural Research Institute (IARI) released semidwarf barley varieties with resistance to yellow rust to farmers on the northern plains in 1974 (*13*). IARI has also successfully developed two maize hybrids that are used widely in India. The most popular hybrid, Ganga Safed 2, is resistant to bacterial rot and *Phythium* stalk rot (*14*), while Ganga 5 is highly adaptable and is resistant to brown stripe downy mildew (*Sclerophthora rayssiae* var. *zea*) and leaf blight, as well as stem borer. CIMMYT breeders are tapping their own wheat collections and those of others to develop high-yielding lines that resist scab and leaf blotch caused by *Helminthosporium septoria tritici* (*15*). Scientists at IITA discovered resistance to cocoyam blight by examining landraces held in the center's gene bank.

Chinese wheat breeders have used germplasm from several countries including Austria, Brazil, Canada, and the United States to develop varieties that withstand attack from a wide variety of diseases. If one considers that China is known to harbor all the major diseases of wheat it is clear that Chinese scientists have demonstrated great skill in averting massive crop failures due to pathogens. The last serious outbreak of a wheat disease occurred in Shensi Province in 1964 (*16*).

Wild relatives of crops have been especially useful to breeders searching for sources of disease resistance. In Nigeria, for example, Ceará rubber (*Manihot glaziovii*) was crossed in 1958 with cassava at the Federal Research Station at Moor Plantation to introduce genes for resistance to bacterial blight of cassava. Subsequently, the cross was found to be useful in breeding programs to make cassava more resistant to cassava mosaic disease (*17*). An ICRISAT team located resistance to *Aschochyta* blight of chickpea in a wild species, *Cicer reticulatum*, and successfully transferred this resistance to the cultivated species, *C. arietinum*. IRRI's gene bank collection of wild rice is a valuable source of resistance to viral diseases. Scientists at IRRI discovered that a single accession of *Oryza nivara* from Uttar Pradesh State in India contains the only known gene that confers resistance to grassy stunt virus (*18*). IRRI and national programs have used that *O. nivara* strain to upgrade disease resistance in rice varieties that are now grown on 20 million hectares in Asia.

Gene banks are also used heavily by breeders screening for material that withstands insect attack. After early lines of high-yielding dwarf rice were seriously attacked by pests in the mid-1960's, IRRI developed rice lines with resistance to some important insects. In 1973, for example, scientists in Vietnam and the Solomon Islands used IRRI material as parents in crosses to develop varieties resistant to brown leafhopper (*Nilaparvata lugens*) (*19*). And in Africa, IITA breeders have found cassava varieties that are genetically resistant to mealybug (*Phenacoccus manihoti*) and green spider mite (*Mononychellus tanajoa*), serious pests of the root crop in Africa (*20*). IITA is multiplying resistant clones for distribution to Nigerian farmers, and seeds are being dispatched to national programs throughout Africa.

Tailoring crops to problem soils is another high priority of plant breeders. CIMMYT and EMBRAPA, for example, are screening germplasm collections for bread wheats and triticales that perform well on the acid soils with high aluminum content in central and southern Brazil. Aluminum toxicity reduces root growth and renders plants more vulnerable to drought. When dwarf wheats from Mexico are successfully crossed with landraces from Brazil to develop new high-yielding varieties, the cerrado region may be transformed into an important food-producing region (*21*). IRRI, CIAT, CIP, and IITA are developing lines of rice, cassava, forage plants, potato, and cowpea that thrive on rain-fed, acid soils with high aluminum content (*22*). Tolerance to salinity in rice has been derived primarily from traditional varieties from southern India and Sri Lanka (*23*).

The gene bank at IRRI has also been helpful to rice breeders searching for material tolerant to climatic extremes. Japanese scientists, for example, found that accessions of the Silewah variety gathered in the hills of Sumatra in 1974 are more cold tolerant than cultivars from Hokkaido, even though Silewah is a tropical rice. Collections made in Bangladesh in 1974 during a flood turned up rices that survive in water 5 meters deep. IRRI's evaluation program has identified 2781 accessions that do well in dry areas (*24*).

The value of gene banks is especially evident when they contain material that has vanished elsewhere. *Oryza perennis* from Taiwan is resistant to ragged stunt virus but is now extinct there; fortunately, collections had been made in Taiwan and deposited at IRRI before the island strain disappeared. In Kampuchea, many unique rice cultivars were lost in the 1970's when war disrupted agricultural production. Seeds of many landraces were eaten or rotted, so the lines died out. Fortunately, IRRI's gene bank contains varieties that were collected before the outbreak of political strife, and some of these have been successfully reintroduced. In 1981, for example, IRRI sent 36 Khmer varieties to Kampuchea through the offices of the Oxford Committee for Famine Relief, and a further 103 indigenous varieties were sent to the national program in 1982.

Conclusions

Since the centers of diversity of many important crops are in the Third World, industrialized countries have a stake in the progress of germplasm conservation. Most gene banks now store the germplasm of only the major crops, yet the germplasm of other plants such as timber and fruit trees, medicinal herbs, and plantation crops, as well as nitrogen-fixing bacteria and yeasts should also be safeguarded. Institutions that will focus on germplasm conservation of tropical cash crops are also needed. Many such crops, such as bananas and coconuts, are important as food crops and although some policy-makers have argued that work on plantation crops is properly left to commercial interests, few companies have expressed a desire to establish gene banks. To exclude these crops from germplasm collections would be unwise, since many Third World economies depend on them.

Developments in biotechnology are enhancing the value of gene banks because investigators studying gene synthesis and the recombining of DNA require naturally occurring genes to serve as models and working material. Germplasm collections need to be much more extensively evaluated and documented so that biotechnologists can readily obtain what they need. Currently, the phenotypic characters of accessions are noted rather than the genes of the plants; in the future, the usefulness of gene bank records will depend on the relevant gene symbols being recorded for each accession. Given the enormous benefits that can be derived from plant breeding programs, gene banks are clearly a sound investment deserving the support of governments, universities, and the private sector.

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7. Only major gene banks for each crop are included. Accession totals change as duplicates are eliminated and new material is added. Ranges of storage temperatures are: short (6°C to ambient), medium (0° to 5°C), and long (−10° to −20°C). Acronyms: AICMIP, All India Coordinated Millet Improvement Programme; ARO, Agricultural Research Organization; AVRDC, Asian Vegetable Research and Development Center; CATIE, Centro Agronomico Tropical de Investigación y Enseñanza; CENARGEN, Central National Plant Genetics Resources Agency; CGIAR, Consultative Group on International Agricultural Research; CGI, Crop Germplasm Institute; CIAT, Centro Internacional de Agricultura Tropical; CIMMYT, Centro Internacional de Mejoramiento de Maiz y Trigo; CIP, International Potato Center; CNPT, Centro Nacional de Pesquisa de Trigo; CRRI, Central Rice Research Institute; EMBRAPA, Empresa Brasiliera de Pesquisa Agropecuária; FAL, Institut für Pflanzebau und Pflanzenzuchtung; IARC, International Agricultural Research Center; IARI, Indian Agricultural Research Institute; IBPGR, International Board for Plant Genetic Resources; ICA, Instituto Colombiano Agropecuário; ICARDA, International Center for Agricultural Research in the Dry Areas; ICRISAT, International Crops Research Institute for the Semi-Arid Tropics; IITA, International Institute of Tropical Agriculture; INIA, Instituto Nacional de Investigaciónes Agricolas; INIPA, Instituto Nacional de Investigación y Promoción Agropecuária; INTA, Instituto Nacional de Tecnologia Agropecuária; IBP, Institute of Plant Breeding; IPIGR, Institute of Plant Introduction and Genetic Research; IRRI, International Rice Research Institute; NBPGR, National Bureau of Plant Genetic Resources; NIAS, National Institute of Agricultural Sciences; NSSL, National Seed Storage Laboratory; NVRS, National Vegetable Research Station; ORSTOM, Office de la Recherche Scientifique Outre-Mer; PGRC, Plant Genetic Resources Center; SPBS, Scottish Plant Breeding Station; TISTR, Thailand Institute of Scientific and Technological Research; VIR, All-Union Institute of Plant Industry; and WARDA, West Africa Rice Development Association. Sources: IBPGR, *Directory of Germplasm Collections* (IBPGR, Rome, 1980–1982); IBPGR, Regional Committee for Southeast Asia, *Newsletter* **4** (No. 2), 7 (1980) and **4** (No. 3), 5 (1980); *Crop Germplasm Conservation and Use in China* (Rockefeller Foundation, New York, 1980); *Reunión Sobre Recursos Fitogenéticos de Interés Agrícola en la Región Andina* (CIRF/FAO/IICA/JUNAC, Lima, 28 to 30 April 1981); *Plant Genet. Resour. Newsl.* **49**, 13 (1982); V. A. Johnson and H. L. Beemer (*16*); personal communications from L. N. Bass, D. Bondioli, F. Cardenas Ramos, L. Holly, F. E. Lopez, G. R. Lovell, K. C. Nagel, and D. H. Smith.
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