Crop Genetic Resources of Africa

Volume I

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Status and Diversity of African Germplasm Collections Maintained at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

M. H. MENGESHA and S. APPA RAO

One of the major objectives of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is to act as a world repository for the genetic resources of its mandate crops: sorghum, *Sorghum bicolor* (L.) Moench; pearl millet, *Pennisetum glaucum* (L.) R. Br.; chickpea, *Cicer arietinum* L.; pigeonpea, *Cajanus cajan* (L.) Mill.; and groundnut, *Arachis hypogaea* L.. The Institute also assembles and conserves the germplasm of six minor millets: finger millet; *Eleusine coracana* (L.) Gaertn.; foxtail millet, *Setaria italica* (L.) P. Beauv.; proso millet, *Panicum sumatrense* Roth. ex Roem. & Schult.; barnyard millet, *Echinochloa* species; and kodo millet, *Paspalum scrobiculatum* L.

The usefulness of any world germplasm collection, such as the one assembled at ICRISAT, depends largely on proper sampling from various agroclimatic zones, the long-term safety and viability of the conserved material, the genetic diversity it offers in both cultivated landraces and their wild relatives, the accessibility of healthy seed samples along with their passport and evaluation data, appropriate maintenance of the germplasm accessions to minimize genetic drift, and the availability of a simple, classified and retrievable documentation system.

ORIGIN AND DISTRIBUTION OF CROPS

Sorghum is reported to have originated in the Sudan/Ethiopian border region and has since spread throughout the world (Harlan, 1975; De Wet, 1978; Mann et al., 1983). The distribution of different races and the assembly, evaluation and utilization of sorghum germplasm are described by Prasada Rao and Mengesha (in press). Pearl millet originated in a diffuse belt of Africa, from Sudan to Senegal (Brunken et al., 1977). The diversity of pearl millet germplasm and its utilization are described by Harinarayana et al. (in press) and Kumar and Appa Rao (1988). Well-documented scientific evidence strongly suggests that pigeonpea originated in India (De, 1974; Maesen, 1980). Chickpea, an important crop in the Indian subcontinent, Ethiopia, Iran, Pakistan, Mediterranean countries and Mexico, probably originated in Turkey (Ladizinsky, 1975). The origin of groundnut is reported to be in South America (Gregory et al., 1973; Ramanatha Rao and Sadasivan, 1985).

Primitive landraces of crops that originated in harsh environments can survive in similar environments, as they evolved mainly in response to natural and, to a lesser degree, human selection (Harlan, 1975). Through the same process of survival, they have been forced to utilize their energy to withstand diseases, pests, drought and other stresses. However, the farmer needs more grain to feed a growing world population, and that is partly why he is replacing the adapted, but low-yielding, landraces with new, high-yielding cultivars. In this context, it is vital to salvage and conserve the farmers' landraces and their wild relatives for use in plant breeding. The international agricultural research centers (IARCs) located in different regions of the world are in a unique position to collect and conserve germplasm and make it readily available to scientists everywhere.

GERMPLASM COLLECTION AND ASSEMBLY

To avert food shortages and subsequent famines, we need to accelerate crop improvement programs, starting with the collection and conservation of the vanishing germplasm. Enormous diversity still exists within crops, although it is gradually dwindling. The time to collect the traditional landraces is now, before they are replaced by newly bred, high-yielding cultivars (Harlan, 1975; Hawkes, 1981). In some cases, such as with the Zerazera landraces of sorghum, it is already too late (Mengesha and Prasada Rao, 1981).

Against this background, ICRISAT started an extensive collaborative project on germplasm collection and assembly in the mid-1970s. The 34,914 germplasm accessions assembled at ICRISAT from Africa and those that will be added in the future are for the benefit of all research workers in any country that needs to use them. It must be emphasized here that those countries that continue to contribute germplasm samples for the world collection are the main beneficiaries. First, they can ensure long-term conservation and availability of their vanishing germplasm. Second, they can expect, in their own countries, a high degree of adaptation of the new and high-yielding cultivars that are developed by using their landraces.

Following its establishment, ICRISAT acquired samples of most of the germplasm of its mandate crops from national and regional programs, such as the Ethiopian Sorghum Improvement Program (ESIP), and world collections, such as the Rockefeller Foundation world collection made in the early 1960s. After identifying geographic and taxonomic gaps, expeditions were launched in priority areas in close collaboration with national programs in Africa, often with the cooperation and support of the International Board for Plant Genetic Resources (IBPGR). We also carried out collection missions for special sorghum types, such as the Zerazera landraces from Ethiopia (Prasada Rao and Mengesha, 1982) and the early-maturing, bold-grain types of pearl millet from Ghana (Appa Rao et al., 1985). All the germplasm samples collected are shared equally among the host country, IBPGR and ICRISAT. To date, ICRISAT has launched 41 expeditions in 24 countries in Africa and assembled 34,914 accessions from 47 countries (*see* Table 1).

TABLE 1 Number of germplasm accessions from Africa in the ICRISAT genebank

Country	Sorghum	Pearl millet	Chickpea	Pigeonpea	Groundnut	Minor millets
Algeria	21	0	16	0	0	0
Angola	29	0	0	0	7(1)	0
Benin	197	40	0	0	14	0
Botswana	190	45	0	0	1	0
Burkina Faso	559	587	0	0	61	0
Burundi	115(2)	0	0	0	0	11
Cameroon	2241	918	0	0	6	0
Cape Verde Is.	1	1	0	6	0	0
Central African Republic	39	58	0	0	2	0
Chad	138	62	0	0	15	0
Comoros	0	0	0	0	1	0
Congo	0	3	0	0	6	0
Côte d'Ivoire	1	0	0	0	80	0
Egypt	22	0	53	0	16	0
Equatorial Guinea	0	0	0	0	13	0
Ethiopia	4,464	1	922	14	0	28
Gambia	57	13	0	0	32	0
Ghana	148	246	0	2	53	0
Guinea	0	0	0	0	22	0
Kenya	872	69	1	316(18)	42	326
Lesotho	257	0	0	0	0	0
Liberia	0	0	0	0	12	0
Libya	0	0	0	0	1	0
Malagasy Republic	1	0	0	1	47	0
Malawi	443	245	10	245	146	248
Mali	661	1,044	0	0	161(145)	0
Mauritania	0	1	0	0	0	0
Mauritius	0	0	0	0	26	0
Morocco	8	3	249	0	21	0
Mozambique	42(6)	28	0	10	149	1
Namibia	1	0	0	0	0	0
Niger	408	1,048	0	0	21	0
Nigeria	1,436	1,145	3	43	338	0
Rwanda	150	0	0	5	1	0
Senegal	237	361	0	10	254	0
Sierra Leone	100	55	0	3	22	0
Somalia	125(294)	3	0	0	9	0
South Africa	930	115	0	4	138	4
Sudan	2,385	559	12	0	197(1)	2
Swaziland	201	0	0	0	8	0
Tanzania	437(262)	449	2	221	378(40)	20
Togo	258	104	0	0	11	0
Tunisia	0	0	33	0	0	0
Uganda	1,245	66	0	1	165	617
Zaire	53	0	0	0	108	0
Zambia	291	81	0	25(61)	240(15)	117
Zimbabwe	1,052(11)	436	0	0	504(72)	414
Total	19,815(575)	7,776	1,301	906(79)	3,328(274)	1,788

Note: Numbers in parentheses are in quarantine transit.

One serious concern we have is that germplasm collection missions are usually made when most of the crop is at prime maturity. As a result, the collector may miss early- and late-maturing lines. Therefore, our strategy has been modified to include collecting landraces at different times of the year — if necessary at several times a year from the same locations. The success of any germplasm collection mission depends largely on: the time of collection; the collectors' knowledge of the crops (including their wild relatives), the country and the region; logistic support; proper collection strategies; correct sampling; adequate field records; and the safe and rapid transfer of the collected material to genebanks.

WILD SPECIES GERMPLASM

It is well known that wild relatives are reservoirs of desirable genes for resistance to certain biotic and abiotic stresses. With the recent advances in biotechnology, it may become increasingly possible to transfer desirable genes from distant wild relatives. Accordingly, we are striving to collect and conserve wild relatives of our crops, although our initial emphasis was on cultivated types. So far, we have assembled 935 accessions of 144 wild species for all our crops. This collection is relatively small and our future plans call for accelerated collection of wild relatives from the centers of origin and diversity.

There are a few examples of wild relatives being successfully utilized as sources of desirable traits. In groundnut, where resistance to *Cercospora* leaf spot is not found in the cultivated forms (Singh et al., in press), wild relatives were successfully used as sources of resistance. In pearl millet, a single dominant gene for rust resistance was found in the wild relative *Pennisetum violaceum*; it is also found in the cultivated forms. In sorghum, resistance to shoot fly, *Atherigona soccata*, was not found in the cultivated forms, but was identified in the wild relative *Sorghum aethiopicum*. Similarly, resistance to pod borer, *Heliothis armigera*, was transferred from *Atylosia* into *Cajanus cajan* (ICRISAT, 1982).

GERMPLASM CONSERVATION

For conservation, seed is produced at ICRISAT during the post-rainy season, when good-quality seed that is free from diseases can be obtained. The standing crop is inspected by plant protection experts and only disease- and insect-free seed is harvested. The moisture content of the seed is brought down to 5-7% before storage in cold chambers at 4°C.

After harvesting, threshing and partial drying, seed is brought to a cool and dry short-term holding room where it is prepared and processed for transferring to medium- or long-term storage. All the accessions at ICRISAT are conserved either in medium- or long-term cold storage conditions that meet the international standards proposed by Roberts (1974) and IBPGR (1979). The temperature and humidity of the storage chambers and the viability of the seed viability are monitored regularly.

Our active germplasm collection is held in medium-term storage. The temperature is maintained at +4°C, with 20% RH. To minimize the frequency of rejuvenation and consequent possible genetic drift, relatively large quantities of seed (in each sample 500 g of sorghum, pearl millet and minor millets, 800 g of pigeonpea and chickpea, and 1 kg of groundnut pods) are stored. Seeds are stored in laminated aluminum cans with screw caps that have rubber gaskets to ensure that they are airtight. We draw small samples for distribution to any scientist who needs them. We have monitored seed regularly for 5 years and found that we have around 91% viability after 5 years of conservation.

A long-term store is now ready for the base collection. To maintain the temperature at –20°C, prefabricated modules have been installed and have been under test for the past year. Seeds will soon be transferred to long-term storage. Recently, we have introduced electronic devices to maintain the desired levels of temperature and relative humidity in our cold storage chambers with a built-in alarm system against fire, high temperatures and moisture.

DIVERSITY OF GERMPLASM

All registered accessions of our mandate crops are systematically evaluated according to descriptors developed by ICRISAT and IBPGR. The variation in important morphological and agronomic characters is considerable; the range observed in different crops is given in Table 2. Considerable variation was also recorded when 343 pearl millet accessions were evaluated at five different locations in India, Burkina Faso and Niger. We have recorded the genetic diversity of 500 pigeonpea germplasm accessions that were systematically evaluated in Kenya and 900 chickpea accessions evaluated in Ethiopia. This work has helped to identify and select several desirable genotypes for crop improvement. Continuous effort is made at ICRISAT to identify new sources of diversity. In pigeonpea, for example, the germplasm

TABLE 2 Range of variation in some selected characters of African crop germplasm samples evaluated at ICRISAT

Character	Sorghum	Pearl millet	Chickpea	Pigeonpea	Groundnut
Days to 50% flowering	36-199	36-159	28-96	55-210	19-50
Plant height (cm)	55-655	63-475	16-93	39-385	-
Peduncle exsertion (cm)	0-55	-21-30	-	-	-
Head length (cm)	2.5-71	6-165	-	-	-
Head thickness (mm)	10-290	10-64	-	-	-
Number of tillers	1-15	1-26	-	-	-
Stalk sugar content (%)	12-38	4.9-19.7	-	-	-
Grain color	white to dark brown	white to dark purple	cream to black	white to black	off-white to dark purple
Seeds per pod	-	-	1-2.8	1.6-7.6	1-4
110-seed mass (g)	0.58-8.56	0.27-1.93	4.9-59.4	2.8-22.4	21.8-100.6
Plant width (cm)	-	-	18-70	-	-
Pods per plant	-	-	few-168	-	-
Harvest index (%)	-	-	21.9-64.8	-	-
Seed protein (%)	-	-	15.4-30.9	12.4-29.5	-
Oil content (%)	-	-	-	-	34.8-50.4
Leaflet length (mm)	-	-	-	-	28-79
Leaf width (mm)	-	-	-	-	14-38
Pod length (mm)	-	-	-	-	13-64
Pod width (mm)	-	-	-	-	11-22
Days to maturity	-	-	-	-	90-155

accessions have been classified into a number of well-defined diversity groups, as shown in the Pigeonpea Germplasm Catalogs (Remanandan et al., 1988a, 1988b).

The main purpose in pointing out this range in variation is to underline the potential use of germplasm for crop improvement. Although the variation that has been conserved is very useful, it is still considered small compared with that available in nature. Many remote areas have yet to be explored and collections made. Unfortunately, the continued availability of such germplasm cannot be guaranteed in view of the alarming genetic erosion that is taking place throughout the world. Good examples of such genetic erosion are the absence of the Zerazera and Hegari sorghum landraces in the Gezira province of Sudan and their replacement by newly bred cultivars (Mengesha and Prasada Rao, 1982), and the imminent extinction of the once-popular pearl millet landrace 'Gullisita' in the Punjab (Appa Rao et al., 1986).

GERMPLASM UTILIZATION

The potential use of a germplasm sample is largely unknown at the time of its collection. However, we have seen that a number of desirable characters are identified whenever a diverse group of germplasm samples is evaluated and screened. Even those lines that show susceptibility to a disease or pest may offer a rare source of breeding material for other agronomically desirable traits. For example, sorghum landraces IS 1082, IS 2122, IS 4663, IS 4664, IS 5470, IS 5484, IS 5566 and IS 18551 have been identified as having promising shoot fly resistance, which needs further confirmation. Other sorghum accessions, including IS 620, IS 621, IS 5959, IS 7237, IS 8219, IS 9308, IS 9482 and IS 11234 have promising grain-mold resistance, but they are susceptible to shoot fly and stem borer. In pigeonpea, ICP 7035 has resistance to *Fusarium* wilt and sterility mosaic, but it is susceptible to *Phytophthora* blight. ICP 7065 is resistant to blight, but highly susceptible to both wilt and sterility mosaic (Mengesha, 1984).

Some misunderstanding exists between technology-rich developed countries and gene-rich developing countries about the international collection, conservation, exchange and utilization of plant genetic resources (Mooney, 1980). The concern comes from the fear that certain private and multinational companies might patent and monopolize new, high-yielding cultivars that could be developed by using germplasm originally collected from developing countries. However, the IARCs and IBPGR, as well as the FAO Commission for Plant Genetic Resources and other international and national programs, agree on the timely collection and conservation of the world's germplasm, and on making it readily available to all who need it for crop improvement programs.

CONCLUSION

Considering the worldwide crop improvement programs and in view of the plant breeders' remarkable success in developing high-yielding cultivars, it is obvious that there are significant advantages associated with international germplasm exchange. With timely collection and imaginative methods of seed conservation and exchange, we should be able to save our valuable seeds for present and future use.

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PLANTI PROCEEDINGS NO. 4

INTRODUCTION OF GERMPLASM AND PLANT QUARANTINE PROCEDURES

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EDITORS

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ICRISAT'S Plant Quarantine System for Germplasm Exchange

CP448

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ABSTRACT

The plant quarantine procedures and techniques adopted by ICRISAT for the exchange of seeds of sorghum, pearl millet, pigeonpea, chickpea, and groundnut are described. For the imported germplasm, the procedures include an intermediate quarantine for groundnut cuttings, fumigation, visual and microscopic examination, seed treatment, testing groundnut seeds by enzyme-linked immunosorbent assay (ELISA), and finally growing the seeds in postentry quarantine isolation area (PEQIA) before release to scientists. Similarly, to export the germplasm, regular inspection of crop by scientists during the growing season, collection of healthy seeds followed by fumigation, visual examination and conducting the ELISA test for groundnut are the essential prerequisites before the germplasm is presented to national plant quarantine authorities for issuance of the phytosanitary certificate. During the last 14 years, a total of 152,678 samples of seed and vegetative material of ICRISAT mandate crops were imported from 8 countries, and 701,547 samples exported to 143 countries through the national plant quarantine authorities.

To improve the efficiency of the plant quarantine system in future, the strategies proposed to be explored include (a) use of serological techniques for detecting seedborne viruses, (b) adoption of new disease indexing techniques, and (c) updating information on treatment schedules, procedures, and compilation of information on pests, diseases, and weeds of plant quarantine importance with relevance to ICRISAT's mandate crop

INTRODUCTION

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a nonprofit, scientific, research and training institute receiving support from donors through the Consultative Group on International Agricultural Research (CGIAR). The Institute was established by CGIAR in 1972 at Patancheru, near Hyderabad, Andhra Pradesh, India. Its mandate includes the collection, evaluation, maintenance, utilization, and distribution of sorghum, pearl millet, pigeonpea, chickpea and groundnut germplasm.

As per the memorandum of understanding between the Government of India (GOI) and ICRISAT, unrestricted movement of seeds of five mandate crops into and out of India is permitted after observing the national plant quarantine regulations. Further, GOI recognized ICRISAT Plant Quara