Current Status of Sorghum Genetic Resources at ICRISAT: Their Sharing and Impacts

V Gopal Reddy*, HD Upadhyaya and **CLL Gowda**
[International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India]
*Corresponding author: v.g.reddy@cgiar.org

Introduction

Plant genetic resources are defined as the "Genetic material of plants that is of value as a resource for the present and future generations of people" (IPGRI 1993). The importance of genetic resources was recognized at the inter-governmental platform under the umbrella of the Food and Agriculture Organization (FAO) of the United Nations as the "common heritage of mankind" which should be made available without restriction (FAO 1983).

Sorghum [Sorghum bicolor (L.) Moench] has an immense range of genetic variability available in Africa where domestication first occurred. Further diversity occurred in Asia due to the early introduction of the crop. Landraces and wild relatives of cultivated sorghum from these centers of diversity are rich sources of resistance to diseases, insect pests and other stresses such as high temperature and drought. They are also sources of traits to improve food and fodder quality, animal feed and industrial products. However, this natural genetic diversity is under threat due to the destruction of habitats, commercial agricultural practices, industrial and infrastructural activities, and large-scale adoption of improved cultivars. Collection and conservation of sorghum germplasm has been accelerated in the past four decades to prevent the extinction of landraces and wild relatives of cultivated sorghum. Since then, germplasm collection and conservation have become integral components of crop improvement programs at both national and international levels (Rosenow and Dahlberg 2000).

Global Status of Sorghum Genetic Resources

Sorghum genetic resources are conserved at many centers around the world. At the global level, sorghum germplasm collections consist of approximately 168,500 accessions. The major organizations/countries which maintain sorghum genetic resources are the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India, the National Plant Germplasm System (NPGS) in USA, Ethiopia, Sudan, South Africa, India and China, primarily because they have large crop improvement programs (Rosenow and Dahlberg 2000). One of the largest collections (about 22% of the global total) is held at ICRISAT. In this paper, we report the current status of sorghum genetic resources maintained at ICRISAT, and sharing of germplasm and its impacts.

Initial Attempts at Sorghum Germplasm Collection at ICRISAT

The first major effort to assemble a world collection of sorghum was made in the 1960s by the Rockefeller Foundation in India (Murty et al. 1967). A total of 16,138 accessions belonging to different taxonomic races were assembled from different countries, and IS (International Sorghum) numbers were assigned to them. Of these, only 8961 accessions could be transferred to ICRISAT in 1974 by the All India Coordinated Sorghum Improvement Project (AICSIP), Hyderabad, Andhra Pradesh, India, as the remaining 7177 had lost their viability by then. Special attempts were made by ICRISAT in 1975–76 to recover the missing accessions by obtaining duplicate sets from Purdue University, the National Seed Storage Laboratory, Fort Collins, USA and Mayaguez, Puerto Rico. These efforts resulted in the recovery of 3764 missing accessions, but left a gap of 3413 (excluding the recent addition of 619 accessions). ICRISAT is planning to obtain the missing accessions from Fort Collins, USA.

Current Status

At present, ICRISAT is a major repository for world sorghum germplasm with a total of 36,774 accessions from 91 countries. The collection is estimated to represent about 80% of the variability present in sorghum (Eberhart et al. 1997). Landraces constitute 85.3%, breeding material 13.2%, wild species accessions 1.2% and named cultivars 0.3% of the total collection. The germplasm maintained at ICRISAT consists of five basic races: *bicolor, guinea, caudatum, kafir* and *durra* and their 10 hybrid races. However, the collection is predominantly represented by three races: *durra* (23.5%), *caudatum* (20.6%) and *guinea* (14.8%). Of the 10 hybrid races, only three, *durra-caudatum* (11.5%), *guinea-caudatum* (9.2%) and *durra-bicolor* (7.1%) are common. India, Uganda and Zimbabwe have all the five basic and ten hybrid races (Gopal Reddy et al. 2002). G*uinea-caudatums*, *durra* and their hybrid races are well-represented in Ethiopia, and *caudatum* and its hybrid races in Sudan.

Geographic and Taxonomic Diversity

The world sorghum collection assembled at ICRISAT represents the major diversity centers of sorghum. The countries that have predominantly contributed accessions belonging to different basic races and their hybrid races are summarized in Table 1. The *guinea* race collections are mostly from Benin, Burkina Faso, Gambia, India [working group (WG) *roxburghii*], Malawi, Mali, Mozambique, Senegal, Sierra Leone (exclusively subrace *margaritiferum*), Tanzania, Togo and Zambia. The Southern African Development Community (SADC) countries such as Botswana, Lesotho, South Africa, Swaziland and Zimbabwe have contributed only *kafirs* and their hybrid races. It is to be noted that *kafirs* are photoperiod insensitive at ICRISAT, Patancheru, India. The *caudatums* are from Burundi, Kenya, Rwanda, Sudan, Uganda (mostly WG *nigricans*), Cameroon, Central African Republic, Namibia and Sri Lanka, and the *durras* are from Ethiopia, Niger, Somalia, India, Cameroon, Pakistan, Russia and the CIS countries and Yemen. Taxonomically, the ICRISAT collection is poor in some specific cultivated (WG *rigidum, kaoliang, decrue*) and transplanted (*muskwaari*) sorghums.

The ICRISAT genebank has various types of collections based on traits, season of adaptation, and nature of domestication as suggested by several sorghum scientists/breeders.

Table 1. Summary of the origin of the sorghum germplasm collection maintained at ICRISAT-Patancheru, Andhra Pradesh, India.

Country	Collection organization[1]	Predominant taxonomic races
Benin	FAO/ORSTOM	*Guinea*
Botswana	ICRISAT	*Kafir*
Burkina Faso	FAO/ORSTOM	*Guinea* and its allies
Burundi	ICRISAT	*Caudatum*
Cameroon	ICRISAT	*Caudatum, durra* [muskwaari (transplanted) sorghums]
Central African Republic	ICRISAT	*Durra-caudatum* and *caudatums*
Ethiopia	ICRISAT/IBPGR	*Durra, guinea-caudatum*
Gambia	ICRISAT	*Guinea*
Ghana	ICRISAT	*Guinea, guinea-caudatum*
India	ICRISAT/NBPGR	*Durra, guinea* (*roxburghiis* only)
Kenya	IBPGR	*Caudatum*
Lesotho	ICRISAT	*Kafir*
Malawi	ICRISAT/IBPGR	*Guinea*
Mali	FAO/ORSTOM	*Guinea*
Mozambique	ICRISAT/IBPGR	*Guinea*
Myanmar	ICRISAT	*Bicolors*
Namibia	ICRISAT	*Caudatum* and its allies
Niger	FAO/ORSTOM	*Durra, durra-caudatum, durra-bicolor*
Nigeria	ICRISAT	*Durra-caudatum, guinea*
Pakistan	ICRISAT	*Durra* and its allies
Russia & CIS	NA[2]	*Durra*
Rwanda	ICRISAT	*Caudatum*
Senegal	FAO/ORSTOM	*Guinea*
Sierra Leone	ICRISAT	*Guinea* (exclusively *margaritiferums*)
Somalia	ICRISAT/IBPGR	*Durra*
South Africa	ICRISAT	*Kafir*
Sri Lanka	ICRISAT	*Caudatum*
Sudan	ICRISAT/IBPGR	*Caudatum, durra-caudatum, guinea-caudatum*
Swaziland	ICRISAT	*Kafir*
Tanzania	ICRISAT/IBPGR	*Guinea*
Togo	FAO/ORSTOM	*Guinea*
Uganda	ICRISAT/Makarere University	*Caudatum* (mostly nigricans)
Yemen AR	ICRISAT/IBPGR	*Durra, durra-caudatum, durra-guinea*
Zambia	ICRISAT/IBPGR	*Guinea, guinea-caudatum*
Zimbabwe	ICRISAT/IBPGR	*Durra-caudatum, guinea-caudatum, kafir*

1. FAO = Food and Agriculture Organization of the United Nations; ORSTOM = Institut français de recherche scientifique pour le développement en coopération; IBPGR = International Plant Genetic Resources Institute.
2. NA = Not available.

Accession collection. This includes the available world landrace collection and new accessions assembled by the sorghum Genetic Resources Unit, ICRISAT.

Conversion collection. To augment the use of tropical sorghum germplasm in breeding programs, and to broaden the genetic base, 348 tall, photoperiod-sensitive landraces were converted into photoperiod-insensitive lines, which are highly prized for their superior agronomic characteristics.

Cultivar collection. This collection includes cultivars released by private and public institutions in different countries.

Genetic stock collection. This collection includes genotypes resistant to diseases and pests, stocks with identified genes, and cytoplasmic-nuclear male-sterile (CMS) lines. While the genetic stocks are maintained by selfing, the CMS lines are maintained through hand pollination by their male-fertile maintainer counterparts.

Basic collection. Two types of basic collections based on seasonal adaptation are being maintained: one for postrainy-season adaptation and the other for rainy-season adaptation. These were selected from the world collection and stratified taxonomically, geographically and on the basis of their ecological adaptation at ICRISAT, Patancheru, India.

Wild and weedy sorghums. Although no collection mission was launched exclusively for wild and weedy relatives of sorghum, ICRISAT maintains and conserves a sizable number of wild sorghums assembled/collected during collection missions. Some of these are good sources of resistance to major biotic and abiotic stresses. Most of the wild sorghums were collected while gathering cultivated types or assembled from other gene banks. Several of the diploid wild races such as *verticilliflorum*, *virgatum*, *aethiopicum* and *arundinaceum* were collected in their natural habitats in Sudan bordering Ethiopia where sorghum was considered to have been domesticated (de Wet et al. 1976). Harlan and de Wet's collection of wild sorghums was obtained from Mayguez, Puerto Rico, USA in the early sixties. At present a total of 449 wild sorghums from 23 taxa are conserved in the ICRISAT genebank.

Core Collection

Crop improvement scientists are using a very small proportion of the large germplasm collection. This is because of the lack of information on traits of economic importance, which often show genotype × environment interactions and require replicated multilocation evaluation. Knowing the genotype value for the accessions is helpful in using them in plant breeding programs, but this is a very costly and resource-demanding task owing to the large size of the collection. To overcome this problem, ICRISAT's germplasm research now focuses on studying the diversity of the germplasm collection and developing "core collections", following the concept of Brown (1989). A core collection consisting of 2246 accessions has been developed and is being maintained at ICRISAT, Patancheru, India (Grenier et al. 2001). This consists of approximately 10% of the total landrace collection, but represents the entire genetic and geographical spectrum of the collection. The core collection is an economical, practical and effective method for conservation, maintenance and utilization of the germplasm (Eberhart et al. 1997).

Evaluation, Characterization and Documentation of Genetic Resources

A prerequisite for the efficient utilization of germplasm is that it must be properly evaluated, characterized and documented in a workable retrieval system so that any group of entries carrying desired characteristics can be easily retrieved and used in breeding programs. At ICRISAT-Patancheru, India, a total of 36,325 sorghum accessions have been characterized for 23 important morpho-agronomic characters (quantitative and qualitative) as and when the accessions were received during both rainy and postrainy seasons. The range of variability available in cultivated races and their wild relatives is extensive, both for qualitative and quantitative traits. The range for days to 50% flowering varied from 33 days to 199 days during the rainy season, and from 36 days to 154 days during the postrainy season; plant height varied from 55 cm to 655 cm during the rainy season and from 50 cm to 580 cm in the postrainy season. During the postrainy season basal tillers ranged from 1 to 14; peduncle exertion from 0 cm to 72 cm, panicle length from 2.5 cm to 90 cm, panicle width from 1 cm to 80 cm; grain size from 0.8 mm to 6 mm, 100-grain weight from 0.29 g to 8.92 g; plant pigmentation from tan to pigmented; midrib color from white to brown, panicle compactness and shape from very loose stiff branches to compact oval; glume color from straw to black; glume fully covered to noncovered; grain color from white to black; endosperm texture from completely starchy to completely corneous; threshability from freely threshable to difficult to thresh; grain lustre from lustrous to nonlustrous; and subcoat present or absent. Characterization and passport data were initially documented using the ICRISAT Data Management Retrieval System (IDMRS) program and later converted to System 1032 (a Relational Database Management Software) (Prasada Rao et al. 1995) and currently to MS Access for faster and more efficient management.

Sharing of Germplasm

The ICRISAT genebank has supplied 248,771 sorghum germplasm seed samples to researchers in 105 countries, Asia being the largest recipient. India has contributed significantly to the growth of the germplasm collection in the ICRISAT genebank. In return, scientists from the Indian national research programs have been the largest recipients of germplasm accessions from ICRISAT. Since 1974, 351,846 germplasm samples have been supplied in response to specific requests from institutions/scientists based in India (126,867) and within ICRISAT (224,979). The ICRISAT genebank has restored about 14,615 germplasm accessions to the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, India. The repeated request for some of the germplasm lines is a testimony to the value of these lines in the genetic enhancement of sorghum. For example, the lines IS 18758, IS 1054, IS 5604, IS 6928 and IS 4776 have been requested 196, 189, 123, 117 and 116 times, respectively.

Impacts

Besides the utilization of germplasm in ongoing research at other institutes, 31 sorghum germplasm accessions supplied from the ICRISAT genebank have been directly released as cultivars in 17 countries (Table 2). Notable among these are IS 18758, a popular landrace from Ethiopia belonging to the hybrid race *guinea-caudatum* WG

Table 2. Sorghum germplasm accessions released directly as cultivars in different countries.

Accession number	Country of origin	Year of release	Country of release	Released name
IS 6928	Sudan	1978	India	Moti
IS 8965	Kenya	1980	Myanmar	Shwe-ni 1
IS 2940	USA	1981	Myanmar	Shwe-ni 2
IS 302	China	1980	Myanmar	Shwe-ni 10
IS 5424	India	1980	Myanmar	Shwe-ni 8
IS 30468	Ethiopia	1980	India	NTJ 2
IS 18758	Ethiopia	1983	Burkina Faso	E-35-1
IS 4776	India	1983	India	U P Chari-1
IS 9302	South Africa	1980	Ethiopia	ESIP 11
IS 9323	South Africa	1984	Ethiopia	ESIP 12
IS 2391	South Africa	1989	Swaziland	MRS 13
IS 3693	USA	1989	Swaziland	MRS 94
IS 8571	Tanzania	1989	Mozambique	Mamonhe
IS 23520	Ethiopia	1989	Zambia	Sima
IS 9321	South Africa	1990	Mexico	NA[1]
IS 9447	South Africa	1990	Mexico	NA
IS 13809	South Africa	1990	Mexico	NA
IS 18758	Ethiopia	1990	Burundi	Gambella 1107
IS 9830	Sudan	1991	Sudan	Mugawim Buda-2
IS 3923	Zimbabwe	1994	Botswana	Mahube
IS 23496	Ethiopia	1995	Tanzania	Pato
IS 3924	Nigeria	NA	India	Swarna
IS 18484	India	1984	Honduras	Tortillerio 1
IS 8193	Uganda	2001	Rwanda	NA
IS 8193	Uganda	2001	Kenya	Kari Matama 1
IS 9468	South Africa	2000	Mexico	Marvilla No SOFO 430201092
IS 13444	Zimbabwe	2000	Sudan	Arous el Rimal
IS 29415	Lesotho	2000	Eritrea	Shiketi
IS 15401	Cameroon	2001	Mali	Soumalemba
IS 21219	Kenya	2001	Rwanda	NA
IS 25395	Kenya	2001	Rwanda	NA
IS 33844	India	2002	India	Parbhani Moti

1. NA = Not available.

zerazera. It has been released as a variety in Burundi (as Gambella 1107) and Burkina faso (as E 35-1). This landrace has proved to be a source of useful traits such as excellent grain quality, high grain yield potential, tan plant, straw glume color, resistant to leaf diseases, tolerance to grain weathering and desirable plant type. It has been extensively used in sorghum breeding programs at ICRISAT and in national breeding programs, and dominates the germplasm base of elite materials. Landrace IS 1054 belonging to the race *durra* and subrace *cernuum* is a ruling postrainy-season adapted variety released as M 35-1 in peninsular India. It is known for its cream (straw) colored, large and lustrous grains with high grain and stover yields and moderate resistance to shoot fly. It is regarded as the queen of postrainy season adapted varieties in India. Another landrace, IS 33844 belonging to the race *durra* was released in Maharashtra, India as Parbhani Moti for postrainy-season adaptation in May 2002. It is an excellent *maldandi*-type (predominant postrainy-season sorghum landrace in Maharashtra and Karnataka states of India) variety with large and lustrous grains and high yield. This was selected from a germplasm collection from Ghane Gaon, Sholapur, Maharashtra by ICRISAT genebank staff in 1989. UP Chari-1, the highly popular high-biomass-yielding forage sorghum variety released in India, is a landrace (IS 4776) supplied from the ICRISAT genebank. The benefits drawn from these varieties have been very large, and need to be quantified. Multilocational evaluation of germplasm by ICRISAT scientists in collaboration with scientists of national programs in India, Kenya, Nigeria, Somalia, and Thailand, led to the identification of locally adapted varieties and thus broadened the sorghum genetic base in these countries.

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References

Brown AHD. 1989. The case for core collection. Pages 136–156 *in* The use of plant genetic resources (Brown AHD, Frankel OH, Marshall DR and Williams JT, eds.). Cambridge, UK: Cambridge University Press.

de Wet JMJ, Harlan JR and **Price EG.** 1976. Variability in *Sorghum bicolor*. Page 453 *in* Origins of African plant domestication (Harlan JR, de Wet JMJ and Stemler ABL, eds.). The Hague, Netherlands: The Mountain Press.

Eberhart SA, Bramel Cox PJ and **Prasada Rao KE.** 1997. Preserving genetic resources. Pages 25–41 *in* Proceedings of the International Conference on Genetic Improvement of Sorghum and Pearl Millet, 22–27 Sep 1996, Holiday Inn Plaza, Lubbock, Texas. Lincoln, Nebraska, USA: INTSORMIL/ICRISAT.

FAO. 1983. International undertaking on plant genetic resources. Rome, Italy: Food and Agriculture Organization.

Gopal Reddy V, Kameshwara Rao N, Reddy BVS and **Prasada Rao KE.** 2002. Geographic distribution of basic and intermediate races in the world collection of sorghum germplasm. International Sorghum and Millets Newsletter 43:15–17.

Grenier C, Bramel PJ and **Hamon P.** 2001. Core collection of the genetic resources of sorghum: 1. Stratification based on eco-geographical data. Crop Science 41:234–240.

IPGRI. 1993. Diversity for development. Rome, Italy: International Plant Genetic Resources Institute.

Murty BR, Arunachalam V and **Saxena MBL.** 1967. Classification and catalogue of a world collection of sorghum. Indian Journal of Genetics 27:1–194.

Prasada Rao KE, Gopal Reddy V and **Stenhouse JW.** 1995. Sorghum genetic resources at ICRISAT Asia Center. International Sorghum and Millets Newsletter 36:15–19.

Rosenow DT and **Dahlberg JA.** 2000. Collections, conversion and utilization of sorghum. Pages 309–328 *in* Sorghum: origin, history, technology and production (Smith CW and Frederiksen RA, eds.). New York, USA: John Wiley and Sons, Inc.