WORLD SORGHUM GERMPLASM COLLECTION AND CONSERVATION

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INTRODUCTION AND OBJECTIVES

Germplasm is the most important raw material for any crop improvement program, and yet the possible extinction of this invaluable resource is a reality the world has to face (10,18). The origin and early domestication of sorghum most probably took place in the northeast quadrant of Africa, in the Ethiopia-Sudan border area extending westward to Chad (3,8). Other areas in West Africa and Asia are also important centers of diversity. It is in these areas that original landraces still exist but are also endangered (6, 18). If man is to avert food shortages and subsequent famines, he has to accelerate crop improvement programs, starting with the collection and conservation of the vanishing germplasm.

One of the major objectives of ICRISAT is to collect, and to serve as a major repository of the germplasm of its mandate crops, and six minor millets. Sorghum is one of the mandate crops of ICRISAT.

The main purpose is to have in hand the important raw material required for crop improvement. In terms of germplasm utilization, the first beneficiaries of germplasm collection are those countries where the collections are made. This is because promising cultivars that may be developed from this germplasm are likely to be well adapted in their original habitat.

Before the newly bred, high-yielding cultivars reach the farmer, we must collect his centuries-old, traditional landraces that will otherwise be replaced and permanently lost (10). We cannot expect the farmer to wait for us because he needs to grow high-yielding cultivars to produce more food, nor can we afford to let him abandon his landraces. Ton years ag6 Harlan (9) stated that the danger to sorghum germplasm is not nearly as great as that to wheat. Nowadays, several factors such as availability of the various high yielding open-pollinated cultivars and hybrids, and the Sahel drought of the 1970's, have changed the situation. Sorghum germplasm is clearly endangered in many areas. The only solution is therefore to accelerate

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our collection programs and conserve the invaluable germplasm for immediate as well as future utilization. We have an urgent task on hand.

Since its establishment in 1979, the Genetic Resources Unit (GRU) of ICRISAT has launched a number of sorghum germplasm collection missions in several centers of diversity, particularly in Africa and Asia. Several other organizations such as the"Office de la Recherche Scientifique et Technique d'Outre-Mer (ORSTOM)", the "Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres (IRAT)", the International Board for Plant Genetic Resources (IBPGR), the United States Department of Agriculture (USDA), the Indian Council of Agricultural Research (ICAR), and other national and international programs have also collected in Africa and Asia. Wherever possible, the gaps in the world collection are filled by correspondence and through exchanges with other research centers and gene banks.

So far, we have collected only once in several areas of diversity. In order to carry out the work more completely, further pointed and general collections must be made in the same areas but at different times. This will ensure the collection of different types of varying maturity periods. It will also help to retrieve some of the germplasm that is inevitably lost due to adverse environmental and handling conditions in transit, as well as those samples understandably rejected by quarantine authorities.

GERMPLASM ASSEMBLY

The world sorghum germplasm assembly work at ICRISAT started after the Institute was established in 1972. The cereals improvement scientists who joined ICRISAT in the early 1970's brought with them a wealth of experience and sorghum germplasm mainly from East Africa, West Africa, India, and the Arid Land Agricultural Development (ALAD) project. The nucleus of the present world collection was assembled by the Rockefeller Foundation (12, 19, 21).

Although duplicates of the 16,138 samples (IS numbers) of the world sorghum germplasm collection assembled by the Rockefeller Foundation have been left in the countries where the material was originally collected, many of them unfortunately lost their viability before they were transferred to ICRISAT. For instance, out of the original world collection assembled in the 1960's, and stored at Rajendranagar, Andhra Pradesh, India, only 8961 accessions could be transferred to ICRISAT in 1974. About 3000 samples of the missing germplasm lines were later acquired by ICRISAT from Purdue University, the National Seed Storage Laboratory (NSSL), Fort Collins, USA, and Mayaguez, Puerto Rico (18). These acquisitions added rare and early collections from different parts of the world.

COLLECTION

The world sorghum germplasm collection work at ICRISAT is currently developing at an accelerated pace. We also continue our search for the missing accessions of the world collection from other gene banks. In addition to the already assembled world collection, 10,688 new accessions were assembled from 79 countries by organizing collection expeditions in priority areas, and by correspondence. With these new additions, the sorghum germplasm collection at ICRISAT has reached a total of 22,466 accessions (Table 1). In addition, 2697 new accessions recently obtained from 12 countries are under Plant Quarantine for release in 1983. When these lines are released, the collection at ICRISAT will reach 25,163 accessions.

TABLE 1. Sorghum germplasm assembled at ICRISAT (January 1983)

Source	No. of accessions assembled by		Total
	Rockefeller Foundation	ICRISAT/IBPGR/ ORSTOM/National Programs	
AFRICA			
Angola	23	6	29
Benin	1	3	4
Botswana	28	162	190
Cameroon	1753	82	1835
Central African Republic	37	2	39
Chad	125	13	138
Egypt	15	7	22
Ethiopia	1446	2796	4242
Ghana	11	53	64
Ivory Coast	1	-	1
Kenya	313	448	761
Lesotho	-	8	8
Malagasy Republic	-	1	1
Malawi	58	379	437
Mali	95	16	111
Morocco	-	3	3
Mozambique	-	42	42
Namibia	-	1	1
Niger	25	383	408
Nigeria	897	276	1173
Senegambia	12	282	294
Sierra Leone	-	3	3
Somalia	5	120	125
South Africa	483	243	726
Sudan	855	1401	2256
Swaziland	18	1	19
Tanzania	31	401	432
Uganda	471	141	612

TABLE 1. (cont'd)

Source	No. of accessions assembled by		Total
	Rockefeller Foundation	ICRISAT/IBPGR/ ORSTON/National Programs	
Upper Volta	160	88	248
Zaire	24	-	24
Zambia	3	207	210
Zimbabwe	123	63	186
ASIA			
Afghanistan	5	1	6
Bangladesh	-	9	9
Burma	2	6	8
China	24	44	68
India	2732	1406	4138
Indonesia	6	26	32
Iran	6	1	7
Iraq	2	2	4
Israel	22	-	22
Japan	106	5	111
Lebanon	-	360	360
Nepal	7	1	8
Pakistan	18	11	29
Philippines	1	4	5
Saudi Arabia	-	1	1
South Korea	2	-	2
Sri Lanka	-	25	25
Syria	-	4	4
Taiwan	12	1	13
Thailand	5	-	5
Turkey	1	50	51
Yemen	-	216	216
Yemen D.R.	-	1	1
USSR	5	64	69
EUROPE			
Belgium	-	1	1
Cyprus	1	—	1
France	5	—	5
German D.R.	-	4	4
Greece	1	-	1
Hungary	-	26	26
Italy	8	-	8
Portugal	-	6	6
Spain	-	3	3
U.K.	-	1	1

TABLE 1. (cont'd)

Source	No. of accessions assembled by		Total
	Rockefeller Foundation	ICRISAT/IBPGR/ ORSTON/National Programs	
AMERICA			
Argentina	2	14	16
Cuba	1	2	3
El Salvador	-	1	1
Guatemala	-	6	6
Honduras	-	1	1
Mexico	207	27	234
Nicaragua	—	1	1
Uruguay	—	1	1
USA	1208	671	1879
Venezuela	-	1	1
West Indies	—	3	3
AUSTRALIA AND OCEANIA			
Australia	6	22	28
Papua New Guinea	—	1	1
UNKNOWN	370	27	397
TOTAL	11778	10688	22466

Types of Collections Maintained at ICRISAT

The various types of collections for maintenance have been identified and described by various individuals, committees and organizations (12). The Rockefeller Foundation and the All India Coordinated Sorghum Improvement Project have played leading roles in the initial stages (7, 21). Presently, ICRISAT (18) has taken the responsibility of world collection, maintenance, and conservation of sorghum germplasm.

1. Accession Collection: This includes the available (past and present) world collection and all the new accessions. So far we have 22,466 accessions, each represented by a sample of 500 g.

2. Basic Collection: A basic collection of 1245 accessions was selected from the world collection with stratification based on taxonomic race, geographical distribution, and ecological adaptation to the Patancheru location. Similar basic collections may have to be formed for other areas. The present material is

being closely observed and used by sorghum breeders in ICRISAT as well as in Cameroon, Guatemala, India, Japan, Mali,Uganda, Upper Volta, and USA.

3. Spontaneous Collection: This consists of wild relatives and weedy races of sorghum. So far, we have been able to maintain 278 accessions of 13 taxa.

4. Bulks Collection: We are now at the initial stage of making bulks. The collection requires careful observation and assessment before merging similar material in a number of bulks. House (12) suggested that entries in one bulk should be similar in origin, height, maturity and adaptation. We are now selecting different series of similar material in the conversion program to maintain them as bulks.

5. Named Cultivar Collection: This collection presently includes only 237 named and released cultivars.

6. Genetic Stock Collection: This material includes germplasm with known genotypes that are of special value as source for certain desirable characters such as resistance to a specific disease. Each sample is maintained by selfing, to obtain a stock of about 1 kg, except for the male sterile lines that are maintained by hand pollination between corresponding male sterile and maintainer lines.

The genetic stocks maintained by the Genetic Resources Unit, ICRISAT are listed below:

Promising lines for shoot fly resistance	556
Promising lines for stem borer resistance	212
Promising lines for midge resistance	60
Promising lines for aphid resistance	9
Lines less susceptible to grain molds	515
Lines less susceptible to leaf blight	35
Lines less susceptible to anthracnose	124
Lines less susceptible to rust	43
Lines less susceptible to downy mildew	95
Promising lines for drought resistance	246
Glossy lines	501
Pop-sorghums	36
Sweet-stalk sorghums	41
Scented sorghum	17
Twin-seeded lines	131
Large-glume lines	71
Cytoplasmic A & B lines	186

All resistant stocks are maintained as suggested by the Entomolgy, Pathology and Breeding disciplines and many are still under further testing.

7. Conversion collection: Following the 1976 recommendation made by the IBPGR Advisory Committee on Sorghum and Millets Germplasm (13), we have maintained 176 converted

lines obtained from Texas and Puerto Rico, USA. The ICRISAT conversion program will soon produce additional converted lines from tropical germplasm.

8. Special collections: These collections are being given special attention to mainly assemble and conserve certain important lines selected and developed for their special qualities by various sorghum workers. So far, we have two such collections maintained at ICRISAT. We know there are many more such valuable collections being kept by various, sorghum improvement scientists and we hope to assemble and maintain them at ICRISAT.

Karper's Nursery: This nursery was developed by the late Dr. R.E. Karper in Texas, USA, after the introduction of yellow endosperm, "kaura" germplasm from Northern Nigeria. These lines are short, basically photoperiod insensitive. They were assigned IS numbers and formed part of the world collection.

ALAD Nursery: This is the material assembled by the Arid Land Agricultural Development (ALAD) Program formerly based in Lebanon, developed by Dr. L.R. House and colleagues at Tel Amara Station, Lebanon. Some of the yellow endosperm "kauras" in the Karper's nursery formed the basic material for this nursery. When Dr. L.R. House left Lebanon, this was sent to ICRISAT for maintenance. There are 1674 accessions in this nursery.

Future Areas of Collection: The priority areas for future collection of sorghum germplasm are the following, as listed by Mengesha and Rao (18).

- Asia: Nepal, Burma, Indonesia, India, Pakistan.
- Eastern Africa: Ethiopia (isolated areas), southern Sudan, Uganda, Kenya, Mozambique, Zimbabwe.
- West Africa: Sierra Leone, Ghana, Togo, Ivory Coast, Chad, Benin, Mauritania, Upper Volta.
- Other Areas: South & North Yemen, China, Turkey, Syria, Central African Republic, Congo, Zaire, Angola, Morocco, Saudi Arabia.

The priority areas are identified in collaboration with the FAO/IBPGR, ICRISAT scientists, various other international and national scientists in germplasm resource areas. New and important collection areas are identified annually based on fresh information received about genetic erosion. Our operational capability depends on several factors including government clearance, financial resources, collaboratin national organizations, environment, and other logistical problems.

EVALUATION AT ICRISAT

More than 19000 accessions have been evaluated (15) for important morpho-agronomic characters. The sorghum Descriptors (15), recently published in collaboration with the IBPGR, will promote a more systematic and uniform evaluation and exchange of information around the world. The variation we have in sorghum germplasm is summari ed in Table 2. This diversity, which is still expanding, is considered the most important aspect of germplasm collection and utilization.

TABLE 2. Range of variation in the presently assembled world sorghum germplasm.

Character	Range	
Days to 50% flowering	36	199
Plant height (cm)	55	655
Peduncle exsertion (cm)	0	55
Midrib color	White	Brown
Panicle length (cm)	2.5	71
Panicle width (cm)	1	29
Glume color	Straw	Black
Glume covering	Exposed	Covered
Grain color	White	Dark brown
Grain size (mm)	1	7.5
100 grain weight (g)	0.58	8.56
Tillering (No.)	1	15
Stalk sugar content (%)	12	38

Screening sorghum germplasm for insect, disease, *Striga* and drought resistance, grain quality, and other characters is being carried out in collaboration with other disciplines. The results of the sorghum evaluation and screening work is shown in Table 3.

TABLE 3. Results of sorghum germplasm evaluation and screening

Screened for	No. of accessions	No. of promising lines	Identified and described by
1. Insect resistance			
Shoot fly	11287	556	Sorghum Entomology
Stem borer	15724	212	-do-
Midge	5200	60	-do-

TABLE 3. (cont'd)

Screened for	No. of Accessions	No. of promising lines	Identified and described by
2.Disease resistance			
Grain mold	16209	515	Sorghum pathology
Leaf diseases			
Leaf blight	8978	35	-do-
Anthracnose	2317	124	-do-
Rust	602	43	-do-
Downy mildew	2459	95	-do-
3.Drought resistance	1752	246	Sorghum Physiology and Breeding
4.Other characters			
Low stimulant production for Striga germination	15754	645	Sorghum Breeding
Glossy character	15260	501	Sorghum Physiology & GRU
Popping character	2694	36	Sorghum Breeding
Sweet-stalk character	7200	41	GRU, Biochemistry & Sorghum Physiology

REGIONAL EVALUATION

Evaluation of sorghum germplasm in the rainy season (Kharif) at Patancheru cannot give complete information as most of the tropical germplasm is photoperiod-sensitive. The problem of photoperiod sensitivity of the tropical germplasm has been recognized by several workers (2, 4, 18, 23). ' That is why much importance is placed on multilocation evaluation of germplasm at or close to their original habitat. This project will be conducted at selected regional centers in collaboration with national programs.

Last year, we successfully evaluated the entire Ethiopian sorghum germplasm of 5155 accessions at Nazareth and Arsi-Negelle, Ethiopia. The work was done in close collaboration with the Ethiopian Plant Genetic Resources Center (PGRC/E) and the Ethiopian Sorghum Improvement Project, with the financial support of GTZ, West Germany.

DOCUMENTATION

Data tabulated for 7114 IS numbers were computerized at IS/GR, Colorado, USA, using the EXIR program for easy retrieval.

The same data were transferred to the ICRISAT computer through magnetic tape and a computer printout was brought out in the form of a catalogue. Further to the data already computerized, evaluation data for important descriptors with passport information from IS 10051 onwards, have been tabulated for computerization. By the end of this year, all the sorghum germplasm evaluation data will be entered in the computer for retrieval and diversity analysis.

REJUVENATION AND MAINTENANCE

The samples that reach the critical level of quantity, and/or fall below 85% viability are rejuvenated with maximum care and, as much as possible, without altering the original genotype. However, limited change is unavoidable with every regeneration. The most practical and manageable method of maintaining the genetic purity of sorghum during regeneration is achieved by selfing about 20 representative heads of each line and mixing the selfed seeds and storing a bulk of about half to 1 kg of the freshly harvested and properly dried seed. The need for frequent regeneration is minimized with appropriate conservation practices.

CONSERVATION

Germplasm conservation is as important as collection. Once the germplasm is collected, it must be properly preserved by appropriate techniques as detailed by the IBPGR and many other workers (14, 16). In general, the following points are prerequisites for a sound germplasm conservation system.

1. Seeds must be clean and free of foreign material.

2. Seeds must be dried in a drying room with cool temperature and low relative humidity. The recommended standards for the drying room are 15 C and 15% relative humidity (16). The temperature recommendation may be too low to be practical. Justice and Bass (17) have discussed several methods for determining and reducing the moisture content of seeds in storage and have stated that moisture content of seeds play most important role in affecting their longevity. Seeds should be thinly spread in trays while drying.

3. Initial viability or percentage of germination must be recorded and continued with systematic monitoring for viability during storage. This information is needed to decide the extent and interval of rejuvenation.

4. A temperature of about +4 C and relative humidity of about 30% is regarded safe for medium-term storage and -18 C for long-term storage (5). The moisture content of sorghum seeds falls (in equilibrium) to about 6.4% when the relative humidity is about 15% (20).

5. A sufficient quantity of seed must be stored to ensure genotypic representation, monitoring of. viability, and germplasm distribution. At ICRISAT, we keep about 500 g of each accession in medium-term, active storage. The IBPGR (16) has recommended storing about 12000 seeds of heterogeneous material and about 4000 seeds of homogeneous material in long-term, base storage.

6. Storage containers should be selected carefully. At ICRISAT, we are ordering aluminum cans with hermetic seals for long-term and with airtight screw caps for medium-term cold storage. Plastic bottles with screw caps presently in use will be replaced in due course.

7. Storage chambers: There are several types of chambers used at different places. At ICRISAT, we are constructing modular rooms insulated with 10 cm polyurethane walls, ceiling and floor. The floor is finished in heavy duty galvanised sheet steel. The chambers are assembled in a large room made of concrete walls, ceiling and floor. The medium-term cold storage chamber are kept at about 30% RH with the use of a Rotair Model N.300 dehumidifier. Compressors of 3 hp capacity and air cooled condensers are mounted outside the storage chamber to supply cold air, which is constantly circulated by means of propeller type fans. Each chamber is equipped with a control panel for effective and reliable manual or automatic operation.

8. Duplicate Conservation: For the sake of safety and ease of handling, it is advisable to store the world collection at least at two locations. Presently, several sorghum collections are stored at different places. According to Anishetty, _et al_ (1), relatively large sorghum collections are presently maintained at the places listed in Table 4:

TABLE 4. Major sorghum germplasm collections

Country and organization	Type of collection	Number of accessions	Remarks
Argentina, INTA	active	2700	
Australia, CSIRO	active	1000	
China, CAAS	active	3000	
Columbia, ICA	unspecified	912	
Ethiopia	landraces & cultivars	5000	duplicate at ICRISAT
France, ORSTOM	landraces, wild and weedy types	2626	partly transferred to ICRISAT
France, INRA	cultivar, dwarf, forage and grain	400	
India, NBPGR	landraces	2000	
India, ICRISAT	world collection	22466	duplicate at NSSL
Japan	landraces and cultivars	466	
Madagascar	unspecified	300	
Malawi, Chitedze	landraces & wild type	483	
Mexico, INIA	introduced cultivars	3000	
Romania	landraces, wild and weedy	4900	
Thailand	unspecified	1500	
USA, NSSL	landraces, cultivars and wild types	15000	duplicate at ICRISAT
USA, Mississipi	sweet sorghum and others	4610	
USA, Puerto Rico	landraces and	4000	duplicate at ICRISAT
USSR, Vavilov Institute	landraces, cultivars & wild	9615	
Venezuela	landraces and cultivars	494	
Yemen Arab Rep.	Yemen & introduced	4000	

Attempts are being made to obtain details of the various collections and to transfer the samples to the ICRISAT gene bank.

There is a plan to maintain and conserve the world sorghum germplasm in two other regions, in addition to the two at ICRISAT and Fort Collins. The first new regional collection may be maintained in Niger. The second one is proposed for Central America. These regional conservations are justified because it is becoming gradually more difficult to transfer germplasm from one region to another, mainly because of quarantine limitations.

INTROGRESSION AND CONVERSION

Conversion is a useful tool for an effective and easy flow of tropical germplasm into various sorghum' improvement programs (2, 4, 12, 22, 23). At present we are in the process of converting "Zera-zera" landraces from Sudan and Ethiopia, which are highly prized for their superior agronomic characters but are of restricted use because of their photoperiod sensitivity and plant height. The F3 populations of these partially converted "Zera-zeras" have recently produced promising segregants, as is described below:

1. The desirable Zera-zera head characteristic was retained.

2. Improvement of grain yield and quality was observed.

3. The tropical, photoperiod sensitive material was successfully converted to insensitive background.

4. Plant height was reduced to about half that of the original landrace.

We have recently initiated an introgression program by crossing S. propinguum and a promising sorghum cultivar IS 18758 (commonly known as E 35-1) from Gambella, Ethiopia. Preliminary results of this work are promising.

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