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SORGHUM GENETIC RESOURCES—SYNTHESIS OF AVAILABLE DIVERSITY AND ITS UTILISATION

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INTRODUCTION

Sorghum Moench is an immensely variable genus and is sub-divided into sections Chaetosorghum, Heterosorghum, Parasorghum, Stiposorghum and Sorghum (Garber, 1950). Section Sorghum includes cultivated grain sorghum, a complex of closely related annual taxa from Africa, and a complex of perennial taxa from southern Europe and Asia (de Wet, 1978). The range of genetic diversity available among the cultivated sorghums and their wild relatives is truly amazing. Extreme types are so different as to appear to be separate species. Although much of this genetic diversity is still available in areas of early cultivation in Africa, and regions of early introduction into Asia, it is no longer safe to expect that the same situation will exist after another 10 years. Therefore, we are now in a critical, transitional stage where there is an urgent need to collect and conserve the traditional landraces and wild relatives.

It is evident from past progress in sorghum improvement that only a small fraction of the total available collection could be utilised by breeders at any one time. As a prerequisite to efficient utilisation of germplasm, it must be properly evaluated, characterised, and catalogued on the basis of useful genetic characters. Pre-breeding activities such as introgression and conversion are extremely useful in germplasm enhancement. There is a need to utilise the available diversity in developing cultivars for new agricultural and industrial uses.

GERMPLASM ASSEMBLY

The first major attempt to assemble a world collection of sorghum was made in the 1960s by the Rockefeller Foundation in the Indian Agricultural Research Programme (Murty *et al.*, 1967; Rockefeller Foundation, 1970; House, 1985). A total of 16,138 accessions were assembled from different countries and were assigned IS (International Sorghum) numbers. Of these 16, 138 IS numbers, in 1974 only 8,961 could be transferred to ICRISAT by the All India Coordinated Sorghum Improvement Project (AICSIP). Rajendranagar, Hyderabad because by that time the remainder had lost their viability due to lack of proper storage conditions. Special efforts were made by ICRISAT to fill the gaps by obtaining duplicate sets from Purdue University; the National Seed Storage Laboratory, Fort Collins, Colorado, USA, and from Mayaguez, Puerto Rico; this yielded 3,000 of the missing accessions but left a permanent gap of about 4,000 accessions in the world collection presently conserved in the ICRISAT genebank (Mengesha and Prasada Rao, 1982). Collection efforts will continue as long as there are gaps, but it is unlikely that many more will be filled.

At present, ICRISAT is the major repository for world sorghum germplasm with a total collection of 28,072 accessions. Among the major donors the most important are the All India Coordinated Sorghum Improvement Project (AICSIP), Agricultural Universities of India, Ethiopia, Sudan, Cameroon, Nigeria, and the National Seed Storage Laboratory, Fort Collins, Colorado, USA.

Maintenance

All collections are maintained in the post-rainy season by selfing about 20 representative heads from each line. Seeds harvested from these heads are mixed and a bulk of about 500 g is preserved in aluminium cans. One to 2 kilogram samples are maintained as genetic stocks (Table 1); these include all the resistant accessions, stocks with known genes, and cytoplasmic male-sterile lines. Cytoplasmic male-sterile lines are maintained by hand-pollination with their counterpart B lines.

Geographic and taxonomic diversity

The major diversity centers of sorghum are now relatively well-represented in the world collection assembled at ICRISAT. However, the Advisory Committee on Sorghum and Millet Germplasm sponsored by IBPGR/FAO, and ICRISAT have identified conspicuous gaps in the collection and made recommendations for collections, indicating the priority areas. The progress made in recent years in covering geographical gaps is summarised in Table 2.

Despite the generally improved situation at present, there are some countries which were not adequately represented in the world collection such as Morocco, Algeria, Tunisia, Libya, Guinea, Ivory Coast, Central African Republic, Congo, Angola, Somalia, Mozambique, Northern Syria, southern Turkey, Pakistan, China, Nepal and hilly areas of India.

Table 1. Genetic stocks maintained at ICRISAT (1987)

Type	Number of accessions
(i) Promising lines for pest resistance	
Shoot fly (*Atherigona soccata*)	60
Stem borer (*Chilo partellus*)	70
Midge (*Contarinia sorghicola*)	14
Headbug (*Calocoris angustatus*)	6
(ii) Promising lines for disease resistance	
Grain mold	156
Anthracnose (*Colletotrichum graminicola*)	15
Rust (*Puccinea purpurea*)	31
Downy mildew (*Peronosclerospora sorghii*)	155
Striga—low stimulant lines (Lab screening)	645
Striga—resistant lines (Field screening)	24
(iii) Other characters	
Glossy lines	501
Pop sorghum lines	36
Sweet-stalk sorghum lines	76
Scented sorghum lines	17
Twin-seeded lines	131
Large-glume lines	71
Bloomless sorghum lines	207
Broomcorn sorghum lines	52
Cytoplasmic male-sterile and maintainer lines	240

Taxonomically the collection is weak in some specific cultivated subraces, i.e. conspicuum, rigidum, kaoliang, membranaceum, decrue and the transplanted types (Harlan, 1972). Although we have assembled 345 accessions of 23 taxa (Table 3) of wild relatives so far, they form only 1.2 per cent of our total collection. Special collection missions for wild sorghums need to be organised before they become extinct.

Characterisation and range of variation

The entire sorghum germplasm collection except for very recent acquisitions, have been characterised for important morpho-agronomic characters at ICRISAT Center during both the rainy and post-rainy seasons. Morphological and agronomic data, with passport information from IS 1 through IS 25,240 have been documented using the ICRISAT Data Management Retrieval System (IDMRS). Computer printouts of the data are available on request. The observed range of variation in morpho-agronomic characters is summarised in Table 4.

Table 2. Progress made in covering specific geographical gaps in the world collection

Priority area	Collection organisation	Predominent taxonomic races
Africa		
Benin	FAO/ORSTOM	Guinea
Botswana	ICRISAT	Kafir
Burundi	ICRISAT	Caudatum
Gambia	ICRISAT	Guinea
Ethiopia	ICRISAT/IBPGR	Guinea-caudatum
Ghana	ICRISAT	Guinea, Guinea-caudatum
Kenya	IBPGR	Caudatum
Malawi	ICRISAT/IBPGR	Guinea
Mali	FAO/ORSTOM	Guinea
Mozambique	ICRISAT/IBPGR	Guinea
Niger	FAO/ORSTOM	Durra, Durra-caudatum, Durra-bicolor
Nigeria	ICRISAT	Durra-caudatum, Guinea
Rwanda	ICRISAT	Caudatum
Senegal	FAO/ORSTOM	Guinea
Sierra Leone	ICRISAT	Guinea
Somalia	ICRISAT/IBPGR	Durra
South Africa	ICRISAT	Kafir
Sudan	ICRISAT/IBPGR	Caudatum, Durra-caudatum, Guinea-caudatum
Swaziland	ICRISAT	Kafir
Tanzania	ICRISAT/IBPGR	Guinea
Togo	FAO/ORSTOM	Guinea
Zambia	ICRISAT/IBPGR	Guinea, Guinea-caudatum
Zimbabwe	ICRISAT/IBPGR	Durra-caudatum, Guinea-caudatum
Asia		
India	ICRISAT/ICAR/NBPGR	Durra, Guinea
Yemen AR	ICRISAT/IBPGR	Durra, Durra-caudatum, Durra-guinea

UTILISING GENETIC DIVERSITY

Screening for sources of resistance

Traditional landraces and their wild relatives, through centuries of natural and human selection, can be expected to have acquired resistance to specific biotic and abiotic stress factors, and can therefore be used as sources of resistance. Screening the world collection for insect and disease resistance was started soon after it was assembled by the Rockefeller Foundation. Significant progress has been made in India in identifying sources of resistance, and a catalogue of sorghum genetic stocks with resistance to pests and diseases was published by the Indian

Table 3. Wild relatives of sorghum assembled at ICRISAT center as on January 1987

Genus	Section	Species	Subspecies	Race	Sub-race	No. of accessions
Sorghastrum		*Sorghastrum rigidifolium*	—	—		7
Sorghum	Parasorghum	*Sorghum versicolor*	—	—		17
		Sorghum purpureosericeum	*deccanense*	—		5
			dimidiatum	—		3
		Sorghum nitidum	—	—		3
		Sorghum australiense	—	—		3
	Chaetosorghum	*Sorghum macrospermum*	—	—		1
	Stiposorghum	*Sorghum intrans*	—	—		5
		Sorghum brevicallosum	—	—		1
		Sorghum stipodeum	—	—		9
		Sorghum plumosum	—	—		4
		Sorghum matarankense	—	—		3
	Sorghum	*Sorghum halepense*	—	Halepense	Halepense	15
					Jonson grass	5
					Almum	5
				Miliaceum		4
				Controversum		4
		Sorghum propinquum		—		3
		Sorghum bicolor	*drumnondii*	—		86
		Sorghum bicolor	*verticilliflorum*	Verticilliflorum		97
				Arundinaceum		36
				Virgatum		16
				Aethiopicum		13
Total						345

Table 4. Range of variation in selected characters[1]

Descriptors	Range of variation	
Days to 50% flowering (no. of days)	36	199
Plant height (cm)	55	655
Pigmentation	Tan	Pigmented
Midrib colour	White	Brown
Peduncle exsertion (cm)	0	55.0
Head length (cm)	2.5	71.0
Head width (cm)	1.0	29.0
Head compactness and shape	Very loose stiff branches	Compact oval
Glume colour	Straw	Black
Glume covering	Fully covered	Uncovered
Grain colour	White	Dark brown
Grain size (mm)	1.0	7.5
100-seed mass (g)	0.58	8.56
Endosperm texture	Completely starchy	Completely corneous
Threshability	Freely threshable	Difficult to thresh
Luster	Lustrous	Nonlustrous
Subcoat	Present	Absent

[1]See IBPGR/ICRISAT sorghum descriptors.

Council of Agricultural Research (ICAR), and Indian Agricultural Research Institute (IARI), New Delhi (Gupta and Rachie, 1961).

Sorghum germplasm is being screened by scientists from several disciplines for various resistance traits under artificially infested conditions at ICRISAT Center. The results of screening, indicating the number of promising lines identified, are presented in Table 1.

Conversion programme

A major portion of the world collection consists of tall, photoperiod-sensitive landraces, that, as such, are of limited value in crop improvement. In order to augment the use of tropical germplasm in breeding programmes and to broaden its genetic base, we began a tropical conversion programme using the long-day rainy season and the short-day post-rainy season germplasm at ICRISAT Center. We adopted the technique originally developed at Texas A&M University, Texas, USA except that the female parent used in the first cross was the landrace cultivar that also contributes the cytoplasm. Moreover, unlike the converted genotypes from USA, the converted material developed at ICRISAT in India, and partially segregating material selected by breeders during the process of

conversion, is adapted to tropical countries, especially those in the semi-arid tropics. Over the past few years, eight Zerazera landraces from Ethiopia and Sudan have been converted into photoperiod-insensitive lines. It took six years to convert the Sudanese and Ethiopian Zerazeras to photoperiod-insensitivity (ICRISAT, 1985), and the final converted lines are in three maturity and three plant-height backgrounds. All these lines are being assigned ICRISAT Sorghum Conversion (IS-C) numbers.

We are also in the process of converting three more sorghum landraces from Nigeria-Guineense, Kaura, and Farafara. The material is currently in BC_1F_1 generation. The tropical landraces were selected for conversion mainly on the basis of our own original notes made at the time of collection. During the last 3 years, thousands of selections from the partially converted Zerazera populations have to be made by breeders from ICRISAT, AICSIP, Agricultural Universities, and private seed companies in India, and other sorghum breeders from some 20 countries.

Introgression

Interest in the use of exotic germplasm for cereal improvement has markedly increased. Attempts have been made to transfer shoot fly (*Atherigona soccata*) resistance from sugarcane (*Saccharum officinarum* L.) to sorghum (de Wet *et al.*, 1976). Modified sorghums carrying sugarcane genes have been recovered from such crosses, but shoot fly resistance in these sorghums has not yet been reported (Brhane, 1982).

At ICRISAT Center, the available wild relatives for sorghum have been screened for resistance to sorghum shoot fly and sorghum downy mildew (*Peronosclerospora sorghii*), and sources of resistance have been identified.

Since appreciable levels of resistance to shoot fly are not available in any cultivated sorghum, it is necessary to search for resistance in wild species. Crosses were made between resistant wild sorghum species and adapted cultivars during 1985. Presumed hybrids are being grown in a greenhouse. Because the two differ for chromosome number, it is unlikely that hybrids will be fertile. Special techniques, including embryo-rescue, are being used in attempts to produce successful fertile hybrids.

As there are several cultivated landraces with fairly good resistance to sorghum downy mildew, we have not yet attempted to transfer downy mildew resistance from wild sorghums to cultivated genotypes.

ALTERNATE USES OF SORGHUM

Sorghum growing areas in some developing countries are diminishing (FAO, 1985). However, its alternative uses, e.g. as forage, for making beer, alcohol, syrup, etc., could slow down or even reverse this trend. There is a need for sorghum scientists to develop cultivars suitable for new agricultural and industrial uses.

Sorghum for forage

In recent years the search for forage-sorghum genotypes has intensified. The sorghum world collection at ICRISAT Center has been screened by several forage breeders in India, and promising lines have been identified. Suitable forage plant types were found that have such desirable attributes as plant height, profuse leafiness, high seed productivity, and quality characteristics for protein and dry-matter digestibility components (Tripathi and Ahluwalia, 1984).

We are collaborating with the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, in a systematic evaluation of forage sorghum. The evaluation of 1,500 forage-type accessions at Hisar (Haryana), New Delhi, Jhansi (Uttar Pradesh), and Akola (Maharashtra) is in progress. From this multi-locational evaluation, 165 accessions have already been identified as consistently superior at all locations. These will be further tested for use in forage breeding programmes. Interestingly many of these lines came originally from India and the Yemen Arab Republic where sorghum is grown as a dual-purpose crop.

Sorghum for beer

Large-scale urbanisation in Africa has resulted in a shift in sorghum beer production from what used to be a family brew, or at best a community effort, to an industrialised process. Sorghum beer production is a highly specialised industry in South Africa. Most red sorghum collected from Rwanda and Burundi, and some from Ethiopia, are used for making beer; some are also used for making porridge and traditional bread. These collections belong to the race *caudatum* or *durra-caudatum* (Prasada Rao and Mengesha, 1982). More research needs to be done on quality criteria for beer-making, though our present emphasis is on grain for food. The available germplasm collections from eastern and southern African countries provide excellent base material for this purpose.

Sweet-stalk sorghums for syrup and alcohol production

Sorghum landraces that have sweet stalks are sparingly distributed across sorghum-growing areas of Africa and India. The green and tender stalks are chewed like sugarcane. In Ethiopia, sweet-stalk sorghums are also used for confection (Damon, 1962). Schaffert and Gourley (19[illegible]) reported that sweet-stalk sorghums can also be used to produce alcohol by adopting a similar technology to that used to produce sugarcane alcohol.

In view of the growing importance for sweet-stalk sorghums, a part of the world collection maintained at ICRISAT Center was screened for stalk-sugar content (Prasada Rao and Murty, 1982). Calculated on a dry-weight basis, the sugar content of 78 lines under test ranged from 16.2 to 38.1 per cent (Subramaniam and Prasada Rao, unpublished). Suitable lines were identified among collections from Angola, Cameroon, Ethiopia, India, Kenya, Nigeria, Sudan, Uganda, USA and Zimbabwe.

Seed samples of sweet-stalk sorghums have been supplied to scientists in Barbados (West Indies), Bangladesh, Burkina Faso, Ghana, India, Italy, Japan, Thailand, and the Federal Republic of Germany for use in their research programmes.

Conclusions

Some germplasm accessions can be directly recommended for cultivation. For example, E 35-1 (a selection from a Zerazera landrace from Ethiopia) was recommended for release in Burkina Faso (ICRISAT, 1984), and IS 9302 and IS 9323 (Kafir landraces from South Africa) were released in intermediate-altitude areas of Ethiopia (Abebe Menkir and Yilma Kebede, 1984). Germplasm accessions are, however, more commonly used as source material to transfer useful genes into adapted types. Perhaps the most extensive use of primitive and wild material has been in breeding for resistance to diseases and pests.

Much more work on germplasm utilisation has yet to be done. There is far more variability in the present collection than is being used. As a prerequisite to efficient germplasm utilisation, it must be properly evaluated to identify the potential of accessions for use in breeding programmes. Regional evaluation of germplasm at, or close to, its place of origin is vital to exploit the true behaviour and potential of a genotype. Few countries have the incentives or the resources to satisfy these requirements. Therefore, international collaboration in evaluation is not only desirable but essential. ICRISAT is keen to undertake joint, multilocational evaluation programmes with interested national and international organisations. Such efforts will not only strengthen and enhance the utilisation of sorghum germplasm, but could also create opportunities for new uses of the crop throughout the world.

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