# The use of plant genetic resources

*Edited by*

A H D BROWN
*CSIRO Division of Plant Industry, Canberra, Australia*

O H FRANKEL
*CSIRO Division of Plant Industry, Canberra, Australia*

D R MARSHALL
*Waite Agricultural Research Institute, University of Adelaide, Australia*

J T WILLIAMS
*International Board for Plant Genetic Resources, FAO, Rome, Italy*

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# International use of a sorghum germplasm collection

K. E. PRASADA RAO, M. H. MENGESHA, AND V. G. REDDY

## Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most important cereals of the semi-arid tropics. It was probably domesticated in the north-east quadrant of Africa, an area that extends from the Ethiopia Sudan border westward to Chad (Doggett, 1970; de Wet *et al* 1976*b*). From here it spread to India, China, the Middle East and Europe soon after its domestication (Doggett, 1965). Collection and conservation of sorghum germplasm attracted the attention of breeders and botanists about three decades ago, when the vulnerability of landraces following the release of new varieties and hybrids was realized. Experience gained from germplasm collection missions shows that we are now in a critical transitional stage; there is an urgent need to collect and conserve the traditional landraces and their wild relatives.

The range of genetic diversity available among the cultivated sorghums and their wild relatives assembled at ICRISAT is truly amazing. Extreme types are so different as to appear to be separate species. Much of this genetic diversity is still available in areas of early cultivation in Africa and regions of early introduction in Asia. In Africa, genetic variability is available both in the cultivated races and the wild progenitors of the crop. De Wet & Harlan (1971) have reported the distribution of both the wild varieties and the major cultivated complexes of *S. bicolor*, and classified them into races based mainly on spikelet morphology (Harlan de Wet, 1972). This classification is simple to use, and helps to elucidate the variation patterns and reveal the paths of evolutionary history.

However, it is difficult to categorise the variation in cultivated sorghums for economic purposes, merely by examining preserved panicles in herbaria. A knowledge of the useful genes in each accession is important in the use of germplasm for crop improvement. In the 1960s and 1970s,

extensive work was done to elucidate the taxonomic and evolutionary relationships between subspecies and races of *S. bicolor*, but little attention was paid to the possible use of this natural variability to broaden the genetic base for sorghum improvement.

Past research on sorghum improvement can be summarized as follows:

1. Early work on pure-line selection among cultivated landrace populations in Africa and India that resulted in somewhat improved cultivars (Doggett, 1970).
2. Selection among dwarf populations, and subsequent utilisation of cytoplasmic male sterility to develop commercial hybrids (Quinby & Martin, 1954).
3. Conversion programmes initiated to introduce diverse alleles from tropical germplasm into dwarf, photoperiod-insensitive breeding lines from USA (Stephen, Miller & Rosenow, 1967).
4. Expansion of variation by crossing and/or backcrossing between adapted introductions and local types followed by selection. This provided valuable source material from which new lines are being developed for direct release or as parents for hybrids. Part of the collection of yellow-endosperm types has been extensively used (House, 1985).

It is obvious from past progress in sorghum improvement that much work has yet to be done in germplasm utilisation. Only a small fraction of the total available collection can be fully utilised by breeders at any one time. Crop improvement programmes are often interested in portions of the collection that carry desirable traits. As a prerequisite to efficient use of germplasm, accessions must be properly evaluated, characterised and documented with a workable retrieval system so that well-defined sets of samples with specific combinations of desirable traits can easily be retrieved and used in breeding programmes. The world collection of sorghum needs to be evaluated, characterised and catalogued on the basis of useful genetic characters so that it can be effectively used (Brhane, 1982).

This paper deals with the status of the sorghum world collection maintained by the Genetic Resources Unit (GRU) at ICRISAT, its evaluation, documentation and utilisation in the ICRISAT Sorghum Improvement Program and by other institutions.

## Sorghum germplasm collection status at ICRISAT

The first major efforts in the assembly of a sorghum world collection was made in the 1960s by the Rockefeller Foundation in the Indian Agricultural Research Programme (House, 1985; Murty *et al.*, 1967; Rockefeller Foundation, 1970). A total of 16,138 accessions were assembled from different countries and IS (International Sorghum) numbers were assigned. Of these, only 8,961 could be transferred to the ICRISAT gene bank in 1974 because the rest had already lost their viability. Special efforts were made by ICRISAT to fill the gaps by obtaining duplicate sets from the USA (Purdue University, the National Seed Storage Laboratory, Fort Collins, and from Mayaguez, Puerto Rico). This yielded 3,000 of the missing accessions, leaving a permanent gap of about 4,000 accessions in the world collection presently conserved in the ICRISAT gene bank (Mengesha & Prasada Rao, 1982).

The addition of sorghum germplasm to the world collection became the responsibility of ICRISAT in 1974. This is in accordance with the recommendation made by the Advisory Committee on Sorghum and Millets Germplasm sponsored by the International Board for Plant Genetic Resources (IBPGR, 1976). At present, ICRISAT is the major repository for the world sorghum germplasm collection, with a total collection of 26,564 accessions. Organisations such as IBPGR and ORSTOM, in collaboration with national and international institutions and several individuals, have played key roles in the assembly of this collection. The accessions are listed according to their country of origin in Table 4.1. Among donors, the most important are the Ethiopian Sorghum Improvement Project, Ethiopia; Gezira Agricultural Research Station, Sudan; the All India Coordinated Sorghum Improvement Project (AICSIP), and several Indian Agricultural Universities. Almost 80 per cent of the total sorghum collection has come from the developing countries in the semi-arid tropics.

### Types of collection

Several types of collections are maintained at ICRISAT Center. These were established on the recommendations of various sorghum workers (Harlan, 1972).

#### *Accessions collection*

The available world collection and new accessions assembled by ICRISAT. Seed samples of about 500 g of each accession.

#### *Spontaneous collection*

The wild and weedy races (Table 4.2) maintained separately.

Table 4.1. *Sorghum germplasm collection status as ICRISAT up to June 1986*

| Origin | Assembled by Rockefeller Foundation | Assembled by ICRISAT up to June 1986 | Total |
|---|---|---|---|
| *Africa* | | | |
| Angola | 23 | 6 | 29 |
| Benin | 1 | 196 | 197 |
| Botswana | 28 | 162 | 190 |
| Burkina Faso | 160 | 399 | 559 |
| Burundi | — | 70 | 70 |
| Cameroon | 1,753 | 183 | 1,936 |
| Cape Verde Islands | 1 | 1 | 1 |
| Central African Rep. | 37 | 2 | 39 |
| Chad | 125 | 13 | 138 |
| Egypt | 15 | 7 | 22 |
| Ethiopia | 1,446 | 3,018 | 4,464 |
| Ghana | 11 | 137 | 148 |
| Ivory Coast | 1 | — | 1 |
| Kenya | 313 | 559 | 872 |
| Lesotho | — | 8 | 8 |
| Malagasy Rep. | — | 1 | 1 |
| Malawi | 58 | 385 | 443 |
| Mali | 95 | 566 | 661 |
| Morocco | — | 8 | 8 |
| Mozambique | — | 42 | 42 |
| Namibia | — | 1 | 1 |
| Niger | 25 | 383 | 408 |
| Nigeria | 897 | 473 | 1,370 |
| Rwanda | — | 70 | 70 |
| Senegambia | 12 | 282 | 294 |
| Sierra Leone | — | 100 | 100 |
| Somalia | 5 | 120 | 125 |
| South Africa | 483 | 420 | 903 |
| Sudan | 855 | 1,494 | 2,349 |
| Swaziland | 18 | 1 | 19 |
| Tanzania | 31 | 401 | 432 |
| Togo | — | 258 | 258 |
| Uganda | 471 | 141 | 612 |
| Zaire | 24 | — | 24 |
| Zambia | 3 | 288 | 291 |
| Zimbabwe | 123 | 289 | 412 |
| *Asia* | | | |
| Afghanistan | 5 | 1 | 6 |
| Bangladesh | — | 9 | 9 |
| Burma | 2 | 6 | 8 |
| China | 24 | 58 | 82 |
| India | 2,732 | 1,406 | 4,138 |
| Indonesia | 6 | 26 | 32 |
| Iran | 6 | 1 | 7 |



Table 4.1. (*cont.*)

| Origin | Assembled by Rockefeller Foundation | Assembled by ICRISAT up to June 1986 | Total |
|---|---|---|---|
| Iraq | 2 | 2 | 4 |
| Israel | 22 | — | 22 |
| Japan | 106 | 5 | 111 |
| Lebanon | — | 360 | 360 |
| Nepal | 7 | 1 | 8 |
| Pakistan | 1 | 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 Arab Republic | — | 1,306 | 1,306 |
| Yemen, People's Democratic Republic | — | 1 | 1 |
| USSR | 5 | 64 | 69 |
| *Europe* | | | |
| Belgium | — | 1 | 1 |
| Cyprus | 1 | — | 1 |
| France | 5 | — | 5 |
| German Democratic Republic | — | 4 | 4 |
| Greece | 1 | — | 1 |
| Hungary | — | 88 | 88 |
| Italy | 8 | — | 8 |
| Portugal | — | 6 | 6 |
| UK | — | 77 | 77 |
| *America* | | | |
| Argentina | 2 | 14 | 16 |
| Cuba | 1 | 2 | 3 |
| El Salvador | — | 1 | 1 |
| Gautemala | — | 6 | 6 |
| Honduras | — | 1 | 1 |
| Mexico | 207 | 27 | 234 |
| Nicaragua | — | 1 | 1 |
| Spain | — | 3 | 3 |
| Uruguay | — | 1 | 1 |
| USA | 1,208 | 674 | 1,882 |
| Venezuela | — | 1 | 1 |
| West Indies | — | 3 | 3 |
| *Australia and Oceania* | | | |
| Australia | 6 | 22 | 28 |
| New Guinea | — | 1 | 1 |
| Unknown | 370 | 27 | 397 |
| Total | 11,778 | 14,786 | 26,564 |

Table 4.2 *Wild relatives of sorghum assembled at ICRISAT Center up to June 1986*

| Genus | Section | Species | Subspecies | Race | Subrace | Number of accessions |
|---|---|---|---|---|---|---|
| Sorghastrum | | *Sorghastrum rigidifolium* | — | — | | 7 |
| Sorghum | Para sorghum | *Sorghum versicolor* | — | — | | 17 |
| | | *Sorghum purpureosericeum* | *deccanense* | — | | 5 |
| | | | *dimidiatum* | — | | 3 |
| | | *Sorghum nitidum* | — | — | | 3 |
| | | *Sorghum australiense* | — | — | | 3 |
| | Chaeto sorghum | *Sorghum macrospermum* | — | — | | 1 |
| | Stipo sorghum | *Sorghum intrans* | — | — | | 5 |
| | | *Sorghum brevicallosum* | — | — | | 1 |
| | | *Sorghum stipoideum* | — | — | | 9 |
| | | *Sorghum plumosum* | — | — | | 4 |
| | | *Sorghum naturaukense* | — | — | | 3 |
| | Sorghum | *Sorghum halepense* | — | Halepense | Halepense | 15 |
| | | | | | Johnson grass | 5 |
| | | | | | Almum | 5 |
| | | | | Miliaceum | | 4 |
| | | | | Controversum | | 4 |
| | | *Sorghum propinquum* | — | — | | 3 |
| | | *Sorghum bicolor* | *drummondii* | — | | 86 |
| | | *Sorghum bicolor* | *Verticilliflorum* | Verticilliflorum | | 97 |
| | | | | Arundinaceum | | 36 |
| | | | | Virgatum | | 16 |
| | | | | Aethiopicum | | 13 |
| Total | | | | | | 345 |



***Named cultivar collection***

237 named cultivars released by private and public institutions in different countries. Seed samples of 2 kg of each accession are maintained to meet seed requests.

***Genetic stock collection***

Genotypes resistant to diseases and pests, stocks with identified genes, and cytoplasmic-genic male steriles. Seed samples of 1 kg are maintained by selfing, except in the case of male-sterile lines that are maintained by hand pollination (Table 4.3).

***Conversion Collection***

176 IS conversion lines obtained from USA. Seed samples of about 500 g of each accession are maintained. A tropical conversion programme has been initiated at ICRISAT and, after conversion, established lines will be added.

***Basic collection***

A basic collection consisting of 1,275 accessions selected from the world collection and stratified taxonomically, geographically and on the

Table 4.3. *Range of variation in selected characters*

| Descriptors | Range of variation | |
|---|---|---|
| Days to 50% flowering (number 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 | Non-lustrous |
| Subcoat | Present | Absent |

basis of their ecological adaptation at ICRISAT. Seed samples of about 500 g of each accession are maintained. This exercise needs to be repeated at other locations to select comprehensive basic collections for different regions.

**Characterisation and range of variation**

The entire sorghum germplasm collection, except for very recent acquisitions, has been characterised for important morpho-agronomic characters at the ICRISAT Center during both the rainy and post-rainy seasons. The observed range of variation in morpho-agronomic characters is summarised in Table 4.3.

***Documentation and computerisation***

Morphological and agronomic data, with passport information from IS 1 to IS 16676 have been documented using the ICRISAT Data Management Retrieval System (IDMRS) program. Computer print-outs are available on request. Additional data are added to this computer file as they become available. This program has the facility to retrieve the information in full or in part, as well as to retrieve sets of accessions with specific combinations of desirable characters, it is especially useful for identifying accessions to fit specific requirements of breeders.

Computer printouts of evaluation data have already been supplied to sorghum scientists in India, Cameroon, Chad, China, Ethiopia, Federal Republic of Germany, UK, USA and Mexico.

**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 pests, diseases and environmental stresses, and can therefore be used as sources of resistance. Screening the world collection for insect and disease resistance was started soon after is assembly 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 Council of Agriculture Research (ICAR) and the Indian Agricultural Research Institute (IARI), New Delhi (Gupta & Rachie, 1961).

Sorghum germplasm is being screened for resistance traits at the ICRISAT Center by scientists from various disciplines under artificially infested conditions (Taneja & Leuschner, 1985*a*, *b*, Sharma, 1985*a*, *b*; ICRISAT, 1985*a*). The results of screening, indicating the number of promising lines identified, are summarised in Table 4.4.



***Screening for drought resistance***

It would be extremely difficult to systematically screen all the 26,000 accessions assembled to date for this reaction to drought. Thus, a representative sample based on morphological and physiological traits was selected and screened by essentially observing desiccation tolerance, recovery resistance and agronomic score (Peacock *et al.*, 1985). Of the 26 lines sown in 1974, four resistant lines were selected for further testing, to examine the physiological basis of resistance to midseason stresses due to heat and lack of water. Laboratory techniques will eventually be developed to screen germplasm rapidly for drought tolerance, especially those collections from the drier areas of the tropics.

***Screening for crop establishment***

Using a field technique developed at the ICRISAT Center (Soman *et al.*, 1984) good progress has been made in screening 814

Table 4.4. *Genetic stocks collection maintained at ICRISAT Center as of June 1986*

| Type | Accessions |
|---|---|
| Promising lines for pest resistance | |
| Shoot fly (*Atherigona soccata*) | 60 |
| Stem borer (*Chilo partellus*) | 70 |
| Midge (*Contarinia sorghicola*) | 14 |
| Headbug (*Calocoris angustatus*) | 6 |
| Promising lines for disease resistance | |
| Grain mold | 156 |
| Anthracnose (*Colletotrichum graminicola*) | 15 |
| Rust (*Puccinea purpurea*) | 31 |
| Downy mildew (*Peronosclerospora sorghi*) | 155 |
| *Striga* low stimulant lines (Lab screening) | 645 |
| *Striga* resistant lines (Field screening) | 24 |
| 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 A&B lines | 240 |

germplasm accessions for seedling emergence though soil crust, a major problem in the semi-arid tropics.

Over 50 promising lines have been identified using this technique. High soil temperatures reduce seedling emergence in sorghum. In a preliminary study using a laboratory technique developed at ICRISAT Center (Soman & Peacock, 1985) 52 selected germplasm lines were screened for temperature stress. Seven accessions were found to be promising. They could emerge at higher soil temperature.

### *Diversifying the cytoplasm*

The association of T-cytoplasm with southern leaf blight (*Helminthosporium maydis*) in maize became matter of grave concern among plant breeders worldwide. If such a disease should become associated with milo-type serile cytoplasm in sorghum that is at present used in the production of almost all the hybrids in the world, the entire hybrid-sorghum seed industry would be doomed. To avoid such possible hazards associated with using narrow cytoplasm, it is necessary to diversify the male-sterile source in sorghum.

The diversity in the world collection provided an excellent opportunity to advance in this direction. Work is in progress in India and the USA, and several potentially useful diverse cytoplasms have been isolated. Scientists have identified cytoplasms with different sterility responses from those of milo cytoplasm. Among the new male-sterile lines isolated, M 35 1 A, M 31 2 A, VZM2 A, and GI A from India (source yet to be identified) are important. Sterility in IS 12662C cytoplasm was identified by Schertz & Ritchey (1977) as probably different from milo (A1), and released as A2 (Schertz, 1977; Rosenow *et al.*, 1980; Schertz *et al.*, 1981). The sterility mechanism in IS 1112C was probably that of a different cytoplasm and was designated as A3 by Quinby (1980). To identify the sources of cytoplasm, other characteristics including mitochondria, chloroplasts and polypeptides are being studied in India, the USA, and Scotland, U.K. These studies are providing information and useful lines to diversify germplasm in sorghum breeding programmes (Schertz & Pring, 1982).

## Germplasm enhancement

### *Conversion programme*

The US conversion programme (Stephen *et al.*, 1967) provided breeders in temperate areas with the great genetic diversity available in tropical sorghum, especially the sources of resistances to diseases and pests. However, the conversion programme can handle only a small



portion of the available germplasm, and the converted lines so developed are only adapted to temperate areas

A major portion of the world collection consists of tall, photoperiod-sensitive landraces that are of limited value in crop improvement. To augment the use of tropical germplasm in breeding programmes and to broaden the genetic base, we began a tropical conversion programme using the long-day rainy season and the short-day post-rainy season at the ICRISAT Center The technique originally developed at Texas A & M University, Texas, USA, was adopted, except that the female parent used in the first cross is the landrace and contributes the cytoplasm Moreover, unlike the converted genotypes from USA, the converted material developed in India, or the 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*b*), and the final converted lines are in three maturity and three plant-height backgrounds. All these lies are being assigned ICRISAT Sorghum Conversion (ISC) numbers

We are also in the process of converting three 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 past three years, thousands of selections from the partially converted Zerazera populations have been 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. Exotic germplasm varies greatly in its capacity to contribute positively to crop improvement. For this reason, the choice of the appropriate exotic genotype is as important as the choice of the correct adapted cultivar as parent With the possible exception of oat, the cultivated pools of major cereals, including sorghum, contain sufficient genetic variability to permit further genetic gains in yield and other agronomic traits. There appears to be no well-organised introgression programme anywhere that aims to transfer agronomically useful genes from wild to cultivated taxa. This task must be given more emphasis.

Attempts have been made to transfer shoot fly (*Atherigona soccata*) resistance from sugarcane (*Saccharum officinarum* L.) to sorghum (de Wet *et al.*, 1976*a*). Modified sorghums carrying sugarcane genes have been recovered from such crosses whether or not these sorghums have any shoot fly resistance has not been reported (Brhane, 1982).

At the ICRISAT Center, the available wild relatives of 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 sorghums, 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 there are differences in chromosome number it is unlikely that hybrids will be fertile. All possible techniques, including embryo rescue, are being used in our attempts to produce successful hybrids.

As there are several cultivated landraces with fairly good resistance to sorghum downy mildew, we have not yet initiated any work for transferring 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 and for making beer, alcohol, syrup, etc, can slow down or even reverse this trend. There is a need for sorghum scientists to develop new agricultural and industrial uses for sorghum.

#### *Sorghum for forage*

In recent years the search for forage-sorghum genotypes has intensified. The world collection at ICRISAT has been screened by several forage breeders in India and promising lines identified. IS 4133, IS 4866 and IS 11148 were identified as suitable forage plant types possessing such desirable attributes as plant height, profuse leafiness, high seed productivity and comparable quality characteristics for protein and dry-matter digestibility components. A wild genetic base for forage attributes was reported by Tripathi & Ahluwalia, 1984.

We are collaborating with the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, in a systematic evaluation of forage sorghum. Evaluation of 1,500 forage-type accessions at Hisar, New Delhi, Jhansi, and Akola is in progress. Results from this multilocational evaluation should identify the most promising lines for use in forage breeding programmes.



#### *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 affair, to an industrialised process. Sorghum beer production is a highly specialised industry in South Africa. It is distinct from beer made from barley malt in that the usual process of starch conversion and alcohol fermentation is preceded by a souring process which influences the body, stability and alcohol content of the final product (Doggett *et al.*, 1970). The most important characteristic of a sorghum for brewing is its ability to produce amylase upon germination (Novellie, 1982). Most sorghums 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 & Mengesha, 1982). Substantial research remains to be done to establish quality criteria for making beer. The available germplasm collections from eastern and southern African countries provide an 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 a confection (Damon, 1962). Schaffert & Gourley (1982) reported that sweet-stalk sorghums can also be used to produce alcohol by adopting the technology applied to sugarcane.

In view of the growing importance for sweet-stalk sorghums, a part of the world collection maintained at ICRISAT was screened for stalk-sugar content. Calculated on a dry-weight basis of the 78 lines tested, the sugar content ranged from 16.2 to 38.1 per cent (Subramaniam & Prasada Rao, unpublished). The lines were identified among collections from Botswana, Cameroon, Chad, Ethiopia, India, Kenya, Malawi, Niger, Nigeria, Somalia, South Africa, Sudan, Thailand, Uganda, USA, Zambia and Zimbabwe (Prasada Rao & Murty, 1982).

Seed samples of sweet-stalk sorghums have been supplied to scientists in many countries for use in their research programme.

#### *Pop sorghums*

A broad survey of the geographical distribution of pop sorghums in the world collection showed that a majority of them originated in India

(Prasada Rao & Murty, 1982) where popped sorghum grains are consumed as a snack food and as a delicacy. Most of the pop sorghums in India are identified by colloquial names. Of the 3,682 accessions screened for popping quality, 36 showed good popping qualities, and could be useful in breeding programmes that aim to improve this quality (Murty *et al.*, 1982).

***Broomcorn sorghums***

Broomcorns are characterised by a very short rachis and very long panicle branches. The kernels are small and often enclosed in long ellipsoid glumes belonging to the taxonomic race Bicolor. The stalks are dry, non-sweet, and have a hard rind. Inflorescences of broomcorn, with their long panicle branches, are used to make household, warehouse, whisk, and toy or hearth brooms (Weibel, 1970). Broomcorn types apparently developed in the Mediterranean region from material coming from India or Africa via the Middle East. In Italy they were grown before AD, 1596 and their cultivation and the manufacture of brooms spread to Spain, France, Austria and southern Germany. Considerable development of broomcorn subsequently took place in the USA, where it is said to have been introduced by Benjamin Franklin (Doggett, 1970). Spikelets in recently developed cultivars disarticulate before the inflorescences are harvested, eliminating the need for threshing.

In the world collection maintained at ICRISAT, there are 52 accessions belonging to the broomcorn group. Seed samples of these types have been supplied to scientists in Bolivia, Ethiopia, Mexico, Yemen PDR and Yugoslavia for use in their breeding programmes.

**Taxonomic systems and germplasm utilisation**

Of the several classification systems proposed for cultivated sorghums, the most important ones are those of Snowden (1936), Murty *et al.* (1967), and Harlan & de Wet (1972). Among these, the classification system proposed by Harlan & de Wet has gained rapid popularity. The Advisory Committee on Sorghum and Millets has accepted and recommended this system for classifying germplasm at ICRISAT (IBPGR & ICRISAT, 1980).

Harlan & de Wet's classification system recognises five basic races, i.e. Bicolor, Guinea, Caudatum, Kafir, and Durra, and all possible combinations of these races, referred to as intermediate races. It is easy to identify races on the basis of spikelet morphology. This classification system tends to be over-simplified, and is of limited use, particularly from the utilisation point of view. After studying the world collection, and specimens filed at



the Royal Botanic Gardens, Kew, UK, we are working out a 'subrace' classification system which is essentially an extension of the Harlan & de Wet classification. For example, the major cultivars under race Caudatum can be classified thus:

| Cultivar | Harlan | ICRISAT |
|---|---|---|
| Hegari sorghums from Sudan | Race Caudatum | Race Caudatum Subrace: Hegari |
| Beer sorghums from the highlands of Burundi | Race Caudatum | Race Caudatum Subrace Nigricans |

In this subrace classification, it will be possible to reflect the geographic origin as well as the potential of particular landraces to sorghum users. It is known to almost all sorghum scientists that Hegaris are grain sorghums originating from Sudan, and Nigricans are beer sorghums originating from eastern Africa. Information on the subrace will help users to visualise the type of material they are dealing with.

**Availability of germplasm**

If the world collection is to serve a useful purpose, it should be readily available to all research workers, institutions and universities. The supply of seed material to scientists worldwide is one of the major

Table 4.5. *Sorghum germplasm samples distributed up to June 1986*

| Year | ICRISAT Center | Within India | Other countries | Total samples distributed |
|---|---|---|---|---|
| 1973 | — | — | 3 | 3 |
| 1974 | 4,133 | 3 | 359 | 4,495 |
| 1975 | 6,574 | 2,102 | 1,090 | 9,766 |
| 1976 | 3,977 | 1,788 | 2,729 | 8,494 |
| 1977 | 11,691 | 2,812 | 3,446 | 17,949 |
| 1978 | 8,563 | 2,159 | 696 | 11,415 |
| 1979 | 7,870 | 3,720 | 5,785 | 11,375 |
| 1980 | 23,197 | 1,798 | 1,897 | 26,892 |
| 1981 | 36,322 | 3,571 | 9,718 | 49,611 |
| 1982 | 17,556 | 1,668 | 12,795 | 32,019 |
| 1983 | 15,967 | 3,415 | 18,080 | 37,462 |
| 1984 | 17,477 | 2,123 | 14,668 | 34,268 |
| 1985 | 20,979 | 1,816 | 12,376 | 35,171 |
| 1986 | 3,639 | 10,998 | 6,576 | 21,213 |
| Total | 177,945 | 37,973 | 90,215 | 306,133 |

responsibilities of ICRISAT and the promising accessions discussed in this paper are available on request. All exported seed material from ICRISAT must pass through the Indian Plant Quarantine Authority and this passage is facilitated by the Export Certification Quarantine Laboratory established at ICRISAT. Table 4.5 shows the number of sorghum germplasm samples distributed by ICRISAT since 1973.

## Conclusions

Although germplasm collections are useful in elucidating the taxonomic and evolutionary relationships between different species and races, their principal justification is to assemble natural variability that can be used to broaden the genetic base for present and future sorghum improvement.

Some germplasm accessions may 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 into intermediate-altitude areas of Ethiopia (Abebe & Yilma, 1984). Germplasm accessions are, however, more commonly used as source material for transferring useful genes into adapted types. Perhaps the most extensive use of primitive and wild material has been in the breeding for resistances to diseases and pests. The search for various kinds of resistance may be intensified in the future. The transfer of desirable genetic traits from wild to cultivated material depends on cytogenetic and genetic relationships between the respective species. In the case of wide crosses, special techniques including biotechnology may have to be adopted in the future.

Much germplasm utilisation work has yet to be done. There is far more variability in the present collection than that used. As a prerequisite to efficient use, germplasm must be properly evaluated to identify the potential of accessions for use in breeding programme.

Regional evaluation of germplasm at or close, to the place of origin is vital to exploit the true potential of a genotype. Few countries have the desire or the resources to satisfy these requirements. Therefore, international collaboration in evaluation is not only desirable but essential. Such efforts will not only strengthen and enhance the utilisation of sorghum germplasm, but could also create new uses for the crop throughout the world.



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