Current Situation and Future of Sorghum Germplasm

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Collection and conservation of sorghum germplasm was accelerated about two decades ago because of the danger caused to the landraces by the release of new varieties and hybrids. For example, "Zera-zera" and "Hegari" landraces of sorghum once present in the Gezira province of Sudan are now completely out of cultivation (Prasada Rao and Mengesha 1980). Although landraces are still found in Africa and Asia in large areas, it is no longer safe to expect that the same situation will exist after another 10 years. Our recent experience shows that several primitive landraces once abundant in parts of Africa and Asia are now extinct. Therefore, we are now in a critical, transitional stage when there is an urgent need to collect and conserve the traditional landraces and their wild relatives at an accelerated pace.

The first major effort in the assembly of a world collection of sorghum was made in the sixties by the Rockefeller Foundation in the Indian Agricultural Research Program (House 1980; Murty, et al. 1967; Rockefeller Foundation 1970). A total of 16 138 accessions were assembled from different countries and were assigned I.S. (at that time "Indian Sorghums") numbers. An assessment of this collection indicated that only half the total number of the accessions is an authentic-indigenous collection representing field collections with sufficient information about its origin (Harlan 1972).

Of these 16 138 I.S. numbers only 8961 could be transferred to ICRISAT by the All India Coordinated Sorghum Improvement Project (AICSIP), Rajendranagar, India, in 1974 because the remainder had lost their viability due to a lack of proper storage facilities before they could be transferred to ICRISAT. Special efforts were made by ICRISAT to fill the gaps, by obtaining duplicate sets from Purdue University; the National Seed Storage Laboratory, Fort Collins, USA, and from Mayaguez, Puerto Rico; this yielded 3000 of the missing accessions thus leaving a permanent gap of about 4000 accessions in the world collection presently conserved in the ICRISAT gene bank (Mengesha et al. 1979). The efforts will continue as long as there are gaps. However, it is unlikely that many more will be retrieved.

Assembly of Germplasm

The addition of sorghum germplasm to the world collection that had been assembled by the Rockefeller Foundation, became the responsibility of ICRISAT and is being carried out in accordance with the recommendations made by the Advisory Committee on Sorghum and Millets Germplasm sponsored by the International Board for Plant Genetic Resources (IBPGR)/FAO (IBPGR 1976b).

The year-by-year collection and assembly is shown in Figure 1. So far there have been 9486 new accessions from 68 countries through collection expeditions and correspondence. All germplasm that is. imported to ICRISAT must first be received, inspected and released by the Quarantine Authority of the Government of 'India. The Central Plant Protection Training Institute (CPPTI), Ministry of Agriculture, located at Rajendranagar, is charged with the responsibility of quarantine clearance for the importation of ICRISAT's major crops.

At present, ICRISAT is the major repository for the world sorghum germplasm with a total collection of 21 264. The accessions listed according to

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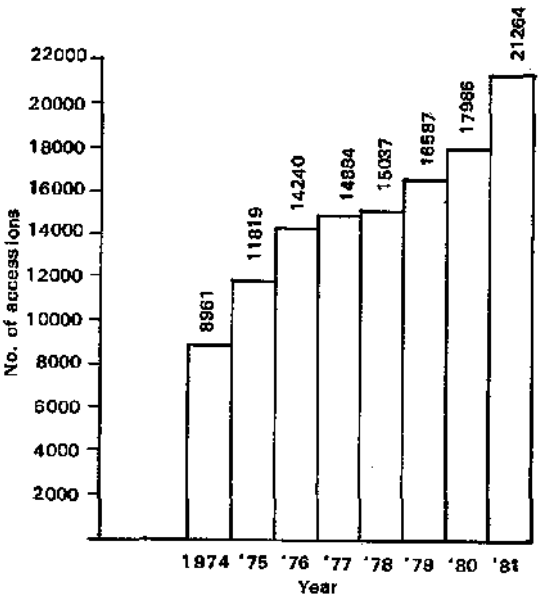

Figure 1. Sorghum germplasm collection and assembly at ICRISAT from 1974 to 1981.

their country of origin can be seen in Table 1. Among the major donors, the most important ones are the Ethiopian Sorghum Improvement Project, Ethiopia, Gezira Agricultural Research Station, Sudan, and the All India Coordinated Sorghum Improvement Project and agricultural universites of India. It is also interesting to note that about 80% of the total sorghum collection has come from the developing semi-arid tropics.

Past Collection Missions

As of today, the countries relatively well-represented are Ethiopia, India, Sudan, and Cameroun, for these have contributed more than half of the present world collection. The Advisory Committee on Sorghum and Millets Germplasm sponsored by IBPGR/FAO, and ICRISAT identified conspicuous gaps in the collection and made recommendations for collections indicating the priority areas (IBPGR 1978 and 1979). The progress made in recent years in covering the specific geographical gaps is summarized in Table 2.

Priority Areas of Future Collection

Priority areas of collection are determined by the extent of genetic erosion that different areas of diversity face and not necessarily by the abundance of germplasm that exists (IBPGR 1976a). In view of the urgency of the task, those areas that are known to have landraces, and those that are threatened by accelerated breeding programs and for other reasons are given high priority for collection. Such priority areas of collection are identified in consultation with sorghum scientists around the world. The best forum for such activity has so far been the IBPGR/FAO Advisory Committee on Sorghum and Millets Germplasm. In our opinion, IBPGR's effort in this area is commendable. Furthermore several individuals, institutes, organizations and foundations have made substantial contributions in identifying priority areas for sorghum germplasm collection throughout the world (IBPGR 1976b; Harlan 1972; 1976; Gebrekidan 1979).

Figure 2 shows the important areas of collection worldwide and the priority areas for the present and future collection are shown in Table 3. New areas could be added to the list as we get fresh information from sorghum workers. Recently, for example, there have been strong recommendations that we should explore the sorghum germplasm in some parts of Central and South America which have previously received little attention.

Collection Strategies

Two distinct methods are followed in our collection strategies. They are general germplasm collection and pointed collection. A general collection is usually from a new and priority area *of* collection for the purpose of collecting and conserving random representatives of the available germplasm. A pointed collection is mounted in a well-known area where a special effort is made to recover specific characters with different agronomic background. Obviously, both types of collection are useful for specific purposes. The world collection can be enriched through cooperation of scientists and collaboration between national and international organizations and agencies. Nowadays, the thrust in germplasm collection and conservation is further strengthened by a number of national organizations in the areas of concern.

Table 1. Sorghum germplasm collection status at ICRISAT (May 1981).

S.No.	Source	Assembled by Rockefeller Foundation	Assembled by ICRISAT up to May 1981	Total
	Africa			
1	Angola	23	6	29
2	Benin	1	3	4
3	Botswana	28	162	190
4	Cameroun	1 753	82	1 835
5	Central African Republic	37	2	39
6	Chad	125	13	138
7	Egypt	15	7	22
8	Ethiopia	1446	2 667	4113
9	Gambia	1	—	1
10	Ghana	11	53	64
11	Ivory Coast	1	—	1
12	Kenya	313	448	761
13	Lesotho	—	7	7
14	Malagasy Republic	—	1	1
15	Malawi	58	312	370
16	Mali	95	16	111
17	Morocco	—	3	3
18	Namibia	—	1	1
19	Niger	25	383	408
20	Nigeria	897	276	1 173
21	Senegal	11	219	230
22	Sierra Leone	—	3	3
23	Somalia	5	120	125
24	South Africa	483	176	659
25	Sudan	855	1 400	2 255
26	Swaziland	18	1	19
27	Tanzania	31	102	133
28	Uganda	471	141	612
29	Upper Volta	160	56	216
30	Zaire	24	—	24
31	Zambia	3	207	210
32	Zimbabwe	123	63	186
	Asia			
33	Afghanistan	5	1	6
34	Bangladesh	—	9	9
35	Burma	2	6	8
36	China	24	44	68
37	India	2 732	1 295	4 027
38	Indonesia	6	26	32
39	Iran	6	1	7
40	Iraq	2	2	4
41	Israel	22	—	22
42	Japan	106	5	111

Continued

Table 1. ***Continued***

S.No.	Source	Assembled by Rockefeller Foundation	Assembled by ICRISAT up to May 1981	Total
43	Lebanon	—	179	179
44	Nepal	7	1	8
45	Pakistan	18	11	29
46	Philippines	1	4	5
47	Saudi Arabia	—	1	1
48	South Korea	2	—	2
49	Sri Lanka	—	25	25
50	Syria	—	4	4
51	Taiwan	12	1	13
52	Thailand	5	—	5
53	Turkey	1	50	51
54	Yemen	—	27	27
55	Yemen D. R.	—	1	1
56	USSR	5	64	69
	Europe			
57	Belgium	—	1	1
58	Cyprus	1	—	1
59	France	5	—	5
60	Greece	1	—	1
61	Hungary	—	22	22
62	Italy	8	—	8
63	Portugal	—	6	6
64	UK		1	1
	Americas			
65	Argentina	2	14	16
66	Cuba	1	2	3
67	El Salvador	—	1	1
68	Gautemala	—	6	6
69	Honduras	—	1	1
70	Mexico	207	27	234
71	Nicaragua	—	1	1
72	Spain	—	3	3
73	Uruguay	—	1	1
74	USA	1 208	659	1 867
75	Venezuela	—	1	1
76	West Indies		3	3
	Australia and Oceania			
77	Australia	6	22	28
78	New Guinea	—	1	1
	Unknown	370	27	397
	Total	11 778	9 486	21 264

At the international level, the sorghum collection and conservation effort is being undertaken by ICRISAT in close collaboration with several national programs, the IBPGR, and FAO. It is also most gratifying to note that the Semi Arid Food Grain Research and Development (SAFGRAD) program and the Institute du Sahel have recognized germplasm collection and conservation as one of their important objectives. The recent establishment of the Pan African Germplasm Collection and Conservation Committee is also considered a move in the right direction.

Experience has shown that well-planned germplasm collection missions are bound to be successful even though they may face some unexpected problems. The planning should be effected ahead of time and in close consultation with all concerned. The most successful and rewarding collection missions so far have been those that were launched jointly in close collaboration between ICRISAT (in our case) and national organizations in the country of collection. Those expeditions that are attempted without proper and advance planning are bound to fail and will become a rather frustrating and costly experience. They may also lead to misunderstanding and strain between cooperating agencies.

In most ICRISAT germplasm collection missions, several organizations, agencies, institutions and individuals have played key roles in the planning and implementation of the mission (Table 4.)

Assignment of I.S. Numbers

As a result of the 1978 recommendation of the ISPGR/FAO Advisory Committee on Sorghum and Millets Germplasm, ICRISAT has been given the responsibility to assign I.S. (International Sor-

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

Priority area	Collection Organization	Remarks
Western Africa		
Mali-	FAO/ORSTOM*	Collection not reached ICRISAT
Niger	FAO/ORSTOM	Mostly guinea sorghums
Togo	FAO/ORSTOM	Collection not reached ICRISAT
Eastern Africa		
Ethiopia (Gambella area)	ICRISAT/IBPGR	Good Zera-Zeras
Malawi	ICRISAT/IBPGR	Mostly guineas
Mozambique	ICRISAT/IBPGR	In transit. Few accessions
Somalia	ICRISAT/IBPGR	Mostly durras
Sudan (Eastern)	ICRISAT/IBPGR	Mostly caudatums and Zera-zeras
Tanzania	ICRISAT/IBPGR	Mostly guineas and caudatums
Zambia	ICRISAT/IBPGR	Mostly guineas
Southern Africa		
Botswana	ICRISAT/IBPGR	Good kafirs and half kafirs
Asia		
India	ICRISAT	Hill sorghums, primitive landraces, scented and pop sorghums.
Philippines	ICRISAT	Very few samples
Sri Lanka	ICRISAT	Very few samples
Yemen	USAID	Not reached ICRISAT

* ORSTOM = Office de la Recherche Scientifique et Technique d'Outre-Mer.
Other accessions have recently been received from China, USSR, Turkey and Hungary.

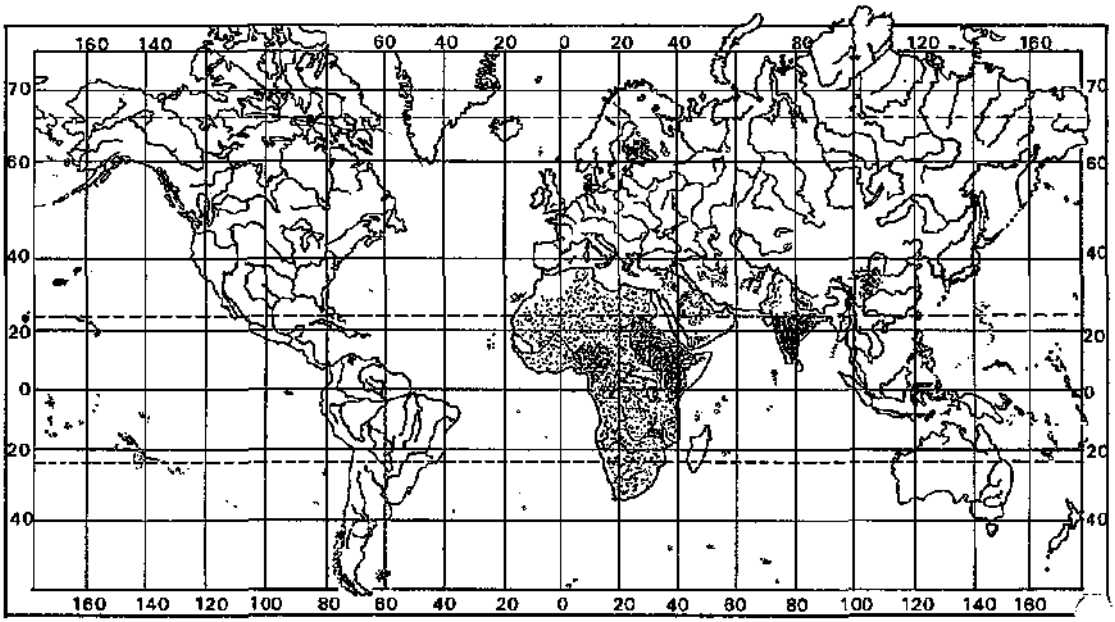

Figure 2. Important areas of sorghum germplasm collection.

Table 3. Priority areas for sorghum germplasm collection.

Area	Status of Collection	Remarks
Africa		
Algeria	not collected	to be explored
Angola	few accessions	to be collected
Benin	very poor representation	to be collected
Burundi	not collected	to be explored
Cape Verde	not collected	to be explored
Central-African Republic	not collected	to be collected
Chad	few accessions	to be collected
Congo	not collected	to be explored
Egypt	few accessions	to be explored
Guinea	not collected	to be explored
Guinea Bissau	not collected	to be explored
Ivory Coast	not collected	to be collected
Libya	not collected	to be explored
Mali	collection not reached ICRISAT	to be assembled or recollected
Mauritania	not collected	to be collected
Mozambique	few accessions	to be collected
Nigeria (north)	partly collected	fuller coverage
Rwanda	not collected	to be explored
Sierra Leone	not collected	to be explored
S. W. Africa	not collected	to be explored

Continued

Table 3. ***Continued***

Area	Status of Collection	Remarks
Togo	Collection not reached ICRISAT	to be assembled
Tunisia	not collected	to be explored
Uganda	partly collected	fuller coverage
Zaire	few accessions	to be collected
Zimbabwe	partly collected	to be recollected
Near East		
Syria	few accessions	to be explored
Lebanon	mostly experimental accessions	to be explored
Jordan	not collected	to be explored
Iran	few accessions	to be explored
Saudi Arabia	not collected	to be explored
Yemen	collection not reached ICRISAT	to be assembled or recollected
Asia		
Afghanistan	few accessions	to be explored
China	few accesions	to be assembled or collected
Pakistan	few accessions	to be collected
India	collected except Assam, Sikkim and some pockets	to be collected
Nepal	not collected	to be collected
Burma	few accessions	to be explored
Laos	not collected	to be explored
Cambodia	not collected	to be explored
Vietnam	not collected	to be explored
Indonesia	few accessions	to be. collected
Philippines	few accessions	to be collected.

Table 4. Cooperators involved in ICRISAT germplasm collection missions.

FAO/IBPGR	National Agencies
1. IBPGR—Rome	1. Ministries of Agriculture.
2. FAO—Country representatives	2. Agricultural Research Institutes.
3. Field-Consultants	3. Universities.
	4. District Agricultural and Administrative Officers.
	5. Crop Improvement Scientists and Students.
	6. Agricultural Extension Agents.
	7. Farmers, above all.

ghum) numbers to the new collection in continuation to the world collection previously assembled by the Rockefeller Foundation. This important task is being implemented in broad consultation and without losing sight of the need to record the original pedigree references. So far, I.S. numbers have been assigned to new germplasm at ICRISAT from I.S. 16139 to I.S. 20887 in continuation of the catalog published by the Rockefeller Foundation. This assignment of I.S. numbers will continue and a catalog will soon be published.

Evaluation and Documentation

The importance of a broad genetic base in evolving new cultivars is well recognized. Conse-

quently the careful evaluation of sorghum germplasm for morpho-agronomic characters—insect, disease, *Striga* and drought resistance—is the first step in the exploitation of genetic variability. The recent development of "List of Sorghum Descriptors" (IBPGR/ICRISAT 1980) will promote a more systematic and uniform system of evaluation around the world, which will in turn enhance a common language and better understanding among sorghum improvement scientists.

The evaluation and characterization of germplasm is continuing. Data tabulated for 7114 I.S. numbers in the 1974 postrainy season and the 1975 rainy season were computerized at IS/GR Colorado using the EXIR program. The same data were transferred to the ICRISAT computer through a magnetic tape and a computer printout was produced in the form of a catalog. The data for the remaining accessions are being compiled for documentation and computerization in a retrieval system. The delay in the documentation is caused by our desire to fill the missing gaps before computerization.

Screening the sorghum germplasm for insect, disease, *Striga* and drought resistance, etc., is being conducted in collaboration with other disciplines (Table 5).

Evaluation of sorghum germplasm in the rainy season (*kharif*) of Patancheru cannot give us complete information, for most of the tropical germplasm accessions are photoperiod sensitive. That is why we place much importance on future evaluation of germplasm near their original habitat. This project could be started at carefully selected regional centers in collaboration with national programs.

In order to have an effective and easy flow of tropical germplasm into various sorghum improvement programs around the world, an Introgression and Conversion Project was initiated in 1976 at ICRISAT Center. Exotic germplasm such as selected landraces from Ethiopia (ET numbers) were crossed and backcrossed to adapted cultivars, 109 selections of the introgressed material were supplied to ICRISAT breeders and the remaining seed is stored for future use by interested sorghum scientists anywhere in the world (Prasada Rao and House 1979). At present we are in the process of converting "Zera-zera" landraces from Sudan and Ethiopia which the highly prized for their superior agronomic characters but are of restricted utility because of their photoperiod sensitivity and plant height.

Table 5. Sorghum germplasm accessions screened at ICRISAT.

Screened for	No. of accessions	No. of promising lines	Described by
Disease resistance	7 429	64	Sorghum Pathology
Insect resistance	7 874	323	Sorghum Entomology
Striga resistance (Lab. screening)	15 504	671	Sorghum Breeding
Drought resistance	1 075	133	Sorghum Physiology & Breeding

Range of Variation

A wide range of variability has been observed in sorghum germplasm for several morpho-agronomic characters such as maturity, plant height, plant pigmentation, midrib colors, head length and width, head compactness and shape, glume color, covering, grain color, size and weight, etc. The range of variation is summarized in Table 6.

Types of Collection

The different types of collections maintained ICRISAT are the following, which have been suggested by several sorghum workers (Harlan 1972).

1. Accessions collection: this includes the available world collection and new accession assembled by ICRISAT. A seed sample of about 500 g of each accession is maintained.
2. Spontaneous collection: these are the wild and weedy races that are being maintained separately; at present, the wild and weedy accessions being maintained at ICRISAT are listed in Table 7.

Table 6. Range of variation in selected characters of sorghum.

S.No.	Descriptors	Range of variation	
1	Days to 50% flowering (no. of days)	36	199
2	Plant height (cm)	55	655
3	Pigmentation	Tan	Pigmented
4	Midrib color	White	Brown
5	Peduncle exsertion (cm)	0	55.0
6	Head length (cm)	2.5	71.0
7	Head width (cm)	1.0	29.0
8	Head compactness and shape	Very loose stiff branches	Compact oval
9	Glume color	Straw	Black
10	Glume covering	Fully covered	Uncovered
11	Grain color	White	Dark brown
12	Grain size (mm)	1.0	7.5
13	100-seed weight (g)	0.58	8.56
14	Endosperm texture	Completely corneous	Completely starchy
15	Threshability	Freely threshable	Difficult to thresh
16	Luster	Lustrous	Nonlustrous
17	Subcoat	Present	Absent

Table 7. Wild and weedy sorghum germplasm accessions maintained at ICRISAT.

Sections	Species	Subspecies	Race	No. of accessions
Para Sorghum	*S. versicolor*		—	2
	S. purpureosericeum	—	—	4
	S. dimidiatum	—	—	4
Eu-Sorghum	*S. halepense*	—	halepense	9
			almum	9
	S. bicolor	*arundinaceum*	arundinaceum	6
			virgatum	2
			verticilliflorum	19
			aethiopicum	5
		drummondii	shattercanes	107
				167

3. Named cultivar collection: this collection includes 237 named cultivars released by private and public institutions in different countries. Two kg seed samples are maintained to meet seed requests.
4. Genetic stock collection: this collection includes all the resistant lines, stocks with known genes and cytoplasmic-genic male sterile. One kg seed samples are maintained by selfing except in the case of male-sterile lines which are maintained by hand pollination.
5. Conversion collection: 176 I.S. conversion

lines from USA are maintained. A conversion program at ICRISAT has been initiated and after conversion lines will be added.

6. Basic collection: a basic collection consisting of about a thousand accessions was selected from the world collection and stratified taxonomically, geographically and based on their ecological adaptation at Patancheru location. This exercise needs to be repeated at other locations for the selection of comprehensive basic collections for different regions.

Maintenance

All collections are maintained by selfing about 20 representative heads in each line. Seed harvested from these heads is mixed and a bulk of about 500 g is preserved in bottles. One to two kg samples are maintained for named cultivars and genetic stocks where seed demand is more. Cytoplasmic male-sterile lines are maintained by hand pollination with their counterpart B lines.

Distribution

If the world collection is to serve a useful purpose, it should be readily available to all the sorghum research institutions and agricultural universities. A principal service of the ICRISAT gene bank is to distribute viable and clean seeds to all sorghum improvement scientists who wish to utilize them in their research program. All export of seed material from ICRISAT must pass through the Indian Plant Quarantine Authority which is facilitated by the Export Quarantine Laboratory established at ICRISAT Center. Table 8 shows the magnitude of germplasm distribution by ICRISAT.

Conservation

Germplasm forms the base material for any crop improvement work. All the efforts for collection, evaluation and documentation would be a waste if the germplasm is not maintained and conserved properly. It is very difficult to grow the many thousands of sorghum accessions every 3 or 4 years for rejuvenation. This is an expensive procedure since it requires land, staff, and other facilities for growing and harvesting the crop. Furthermore it is difficult to retain the original characteristics of each accession free from outcrossing, mutation and mechanical mixture. In order to avoid such extra work, time, money and energy, the material must be stored on a long-term basis. Three different types of storage are planned for sorghum germplasm—short-term, medium-term and long-term storages. Short and medium-term cold storage facilities are ready at ICRISAT. The long-term cold storage facility under construction. In addition it is envisaged to use the National Seed Storage Laboratory (NSSL), Fort Collins, Colorado, USA and gene banks in Africa as backup (duplicate) storage for long-term conservation and safety.

The worldwide collection, mobilization and conservation of germplasm has lately caused anxiety in some developing countries. The main reason for that is the fear that the developing countries, where almost all of the sorghum landraces are found, are being robbed of their genetic resources. The paramount factor is that the entire world is gradually losing its landraces. Whatever landrace that still exists in nature must be collected and conserved without delay. That is exactly what the International Centers are trying

Table 8. Sorghum germplasm distribution up to June 1981.

Year	Within ICRISAT	To Indian Institutions	To Institutions abroad	Total no. of samples
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	2 841	3 429	17 961
1978	8 563	2 159	693	11 415
1979	7 870	3 720	5 785	17 375
1980	23 197	1 798	1 897	26 892
1981	14 534	2 489	3 807	20 830

to do. Not only do they collect and conserve the germplasm in their gene banks, but they also encourage and assist developing countries to do the same. In all cases, a duplicate of the collected germplasm is left with the host country. The assembled material in the ICRISAT gene bank belongs to all those who contributed and those who could utilize it in their own environment anywhere in the world. And its distribution from the ICRISAT gene bank is prompt and free of charge.

Our Outlook in the Eighties

1. Continuation of germplasm collection in the priority areas with some emphasis on wild relatives.
2. Evaluation, documentation, analysis and interpretation of the data generated.
   Assessment of our collection efforts in terms of genetic conservation and utilization.
4. Development of regional germplasm evaluation and conservation centers primarily in Africa.
5. Promotion and implementation of special biological studies in germplasm viability, biosystematics, interspecific crosses, conversions and introgressions and population studies in close collaboration with universities and agricultural research institutes of the developed *and* developing nations.
6. Development and utilization of a long-term cold storage facility.
7. Establishment of institutional linkage in genetic resource activities between ICRISAT and other international and national organizations, universities and gene banks.

References

DE WET, J. M. J., and HARLAN, J. R. 1971. The origin and domestication of *Sorghum bicolor.* Economic Botany 25:128-135.

GEBREKIDAN, B. 1979. Sorghum genetic resources in Africa. Ethiopian Journal of Agricultural Science 1:108-115.

HARLAN, J. R. 1972. Genetic resources in sorghum. Pages 1-13 *in* Sorghum in seventies, eds. N. G. P. Rao and L. R. House. New Delhi, India: Oxford and IBH Publishing Co.

HARLAN, J. R., and STEMLER. A. 1976. The races of sorghum in Africa. Pages 465-478 *in* Origins of African plant domestication, eds. J. R. Harlan, J. M J. de Wet, and A. Stemler. The Hague, Netherlands: Mouton.

HOUSE, L. R. 1980. A guide to sorghum breeding. Patancheru, A.P., India: ICRISAT. 231 pp.

IBPGR (International Board for Plant Genetic Resources). 1976a. Priorities among crops and regions. IBPGR/76/8. Rome, Italy: IBPGR.

IBPGR. 1976b. Proceedings of the Meeting of the Advisory Committee on Sorghum and Millets Germplasm, ICRISAT, 3-7 Oct, Hyderabad, India.

IBPGR. 1978. Proceedings of the 2nd Meeting of the Advisory Committee on Sorghum and Millets Germplasm, ICRISAT, 9-12 Jan, Hyderabad, India.

IBPGR. 1979. Proceedings of the 3rd Meeting of the Advisory Committee on Sorghum and Millets Germplasm, ICRISAT, 19-20 Sept, Hyderabad, India.

IBPGR/ICRISAT. 1980. Sorghum descriptors. Rome, Italy: IBPGR.

MENGESHA, M. H., PRASADA RAO, K. E., and APPA RAO, S. 1979. The status of cereals germplasm at ICRISAT. ICRISAT Genetic Resources Unit working paper.

MURTY, B. R., ARUNACHALAM, V., and SAXENA, M. B. L 1967. Classification and catalogue of a world collection of sorghum. Indian Journal of Genetics and Plant Breeding 27 (Special Number):1-312

PRASADA RAO, K. E., and HOUSE L. R. 1979. Introgression of exotic germplasm. Sorghum Newsletter 22:6.

PRASADA RAO, K. E., and MENGESHA, M. H. 1980. Sorghum and millets germplasm collection in Eastern Sudan. Genetic Resources Unit ICRISAT progress report-16.

ROCKEFELLER FOUNDATION 1970. World collection of sorghums. List of pedigrees and origins. Rockefeller Foundation, Indian Agricultural Program, New Delhi, India.