PLANT GENETIC RESOURCES —INDIAN PERSPECTIVE

Proceedings of the National Symposium on Plant Genetic Resources Organised by NBPGR at New Delhi

March 3–6, 1987

Edited by

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NEW DELHI-110012

GERMPLASM ASSEMBLY, CONSERVATION, AND DIVERSITY OF ICRISAT MANDATE CROPS

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INTRODUCTION

One of ICRISAT's major objectives is to act as a world repository for the genetic resources of its mandate crops namely, sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum americanum*), pigeon pea (*Cajanus cajan*), chickpea (*Cicer arietinum*), and groundnut (*Arachis hypogaea*). The Institute also collects and conserves the germplasm of six minor millets : 1. finger millet (*Eleusine coracana*), 2. foxtail millet (*Setaria italica*), 3. proso millet (*Panicum miliaceum*), 4. little millet (*Panicum sumatrense*), 5. barnyard millet (*Echinochloa crusgalli*), and 6. kodo millet (*Paspalum scrobiculatum*).

ORIGIN AND DISTRIBUTION

Sorghum originated in the Sudan-Ethiopian border region and has since spread to all parts of the world (Harlan, 1975; de Wet, 1978). It reached India some 3000 years ago and is now cultivated almost throughout the country. Distribution of different races, their assembly, evaluation, and utilisation of Sorghum germplasm are described by Prasada Rao and Mengesha (1987). Pearl millet originated in West Africa in a diffuse belt from Sudan to Senegal (Brunken *et al*., 1977). It reached India some 3000 years ago through Gujarat state. The diversity of pearl millet germplasm and its utilisation are described by Harinarayan *et al.* (1987). Pigeon pea, an important source of protein in Asia, originated in India (De, 1974; Maesen, 1980). Chickpea, an important crop in the Indian sub-continent, Ethiopia and in the countries around the Mediterranean, originated in Turkey (Ladizinsky, 1975). Groundnut originated in South America (Gregory *et al*., 1973).

ASSEMBLY

To avert food shortages and subsequent famines, we need to accelerate crop improvement programmes, starting with collection and conser-

vation of the vanishing germplasm. Enormous diversity still exists in crops, even though it is gradually dwindling. The time to collect the traditional landraces is now, before they are replaced by newly bred, high-yielding cultivars (Harlan, 1975; Hawkes, 1981). In some cases it is already too late (Mengesha and Prasada Rao, 1981). It is with this knowledge that ICRISAT started an extensive germplasm collection and assembly programme in the mid seventies. It must be emphasised that the genetic resource material assembled at ICRISAT is for the benefit of all workers in any country that need to use it.

Under the leadership of Dr. H. B. Singh, the then Head of Plant Introduction Division, Indian Agricultural Research Institute (IARI), that now has grown to form the present National Bureau of Plant Genetic Resources (NBPGR), India became one of the pioneering countries of the world in collection and conservation of crop germplasm. In collaboration with the Rockefeller Foundation, IARI assembled maize, sorghum, pearl millet and minor millets as early as 1959 (Rachie, 1963). The germplasm was evaluated, classified, and promising lines were identified (Murty *et al*., 1967a; 1967b). Parts of these collections were maintained by various research institutes and universities in India and abroad. The initial collection of pigeon pea that ICRISAT obtained, consists of the germplasm collected and assembled by the former Regional Pulse Improvement Project (RPIP), a joint project of USAID, India, and Iran.

Following its establishment, ICRISAT acquired most of the germplasm available with national and regional programmes, mainly from the All India Coordinated Crop Improvement Programmes, and various countries in Africa. After identifying geographic and taxonomic gaps, expeditions were launched to priority areas in India by ICRISAT scientists in collaboration with the scientists of the agricultural universities and institutes of the Indian Council of Agricultural Research (ICAR). Collection missions in other countries are planned well in advance. Collaborating scientists are identified, and with their help, the areas to be explored, the route to be followed, and the best time to collect in those areas are decided. We also carried out pointed collection missions for special types such as the Zerazera sorghum landraces from Ethiopia (Prasada Rao and Mengesha, 1982), and the early-maturing, bold-grain types of pearl millet from Ghana (Appa Rao *et al.*, 1985). All the germplasm samples collected are shared equally by the host country, IBPGR and ICRISAT. To date ICRISAT has launched 58 expeditions in 37 countries (Table 1), and 65 expeditions to different states within India (Table 2). Recently ICRISAT and NBPGR have jointly developed

Table 1. Details of germplasm collection expeditions made by ICRISAT scientists outside India (1975–1986)

Country	Missions	Samples collected					
		Sorghum	Pearl millet	Pigeon-pea	Chick-pea	Ground-nut	Minor millets
Afghanistan	4	—	—	32	48	—	—
Bangladesh	2	—	—	—	165	—	—
Bolivia	1	—	—	—	—	12	—
Botswana	2	167	64	—	—	8	6
Brazil	2	—	—	—	—	118	—
Burkina Faso	1	40	—	—	—	—	—
Burma	1	4	—	—	—	4	—
Burundi	1	105	2	—	—	—	3
Cameroon	2	440	908	—	—	—	11
Caribbean Islands	1	—	1	222	—	—	—
Ethiopia	3	147	—	—	314	—	—
Gambia	1	56	17	—	—	8	—
Ghana	1	48	135	—	—	34	—
Kenya	3	2	—	399	—	—	—
Lesotho	1	130	—	—	—	—	—
Malawi	2	417	277	251	—	15	190
Malaysia	1	—	—	—	—	43	—
Mali	1	—	—	—	—	5	—
Mozambique	1	42	15	16	—	131	—
Nepal	2	—	—	131	130	—	—
Niger	1	32	—	—	—	—	—
Nigeria	2	215	405	—	—	48	—
Pakistan	2	—	—	—	40	—	—
Philippines	1	—	—	83	—	9	—
Rwanda	1	170	—	—	—	1	1
Sierra Leone	1	125	59	—	—	2	—
Somalia	1	96	3	—	—	7	—
South Africa	1	77	30	5	—	1	—
Sri Lanka	1	23	—	58	—	—	14
Sudan	2	182	26	—	—	5	2
Swaziland	1	96	—	—	—	—	—
Tanzania	4	340	190	—	234	111	35
Thailand	1	—	—	52	—	—	—
Turkey	2	—	—	—	29	—	—
Yemen A. R.	1	171	10	—	—	—	—
Zambia	1	237	25	21	—	80	107
Zimbabwe	2	858	405	3	—	75	243
Total	58	4220	2572	1273	960	717	612

Table 2. Germplasm collection expeditions by ICRISAT scientists in collaboration with national scientists in India

Province(s)	Missions	Samples collected					
		Sorghum	Pearl millet	Pigeon pea	Chick pea	Ground-nut	Minor millets
Andhra Pradesh	11	262	298	77	—	225	—
Assam	2	—	—	49	—	—	—
Bihar	2	—	—	115	—	2	—
Gujarat	3	4	448	108	128	—	—
Haryana	1	—	—	—	47	—	—
Himachal Pradesh	1	1	—	—	—	104	—
Jammu	1	—	—	—	41	—	—
Karnataka	5	167	28	116	85	210	11
Kashmir	1	4	—	—	—	—	—
Kerala	3	—	—	38	—	1	—
Madhya Pradesh	6	303	47	469	7	2	42
Maharashtra	6	57	571	18	25	199	—
Meghalaya	1	—	—	2	—	—	—
Orissa	5	—	46	409	—	4	—
Punjab	1	—	204	7	146	—	—
Rajasthan	4	45	379	30	139	5	—
Sikkim	1	—	—	4	—	—	—
Tamil Nadu	7	9	207	96	—	18	—
Uttar Pradesh	3	63	462	234	83	—	—
West Bengal	1	—	—	—	115	—	—
Total	65	915	2690	1772	816	770	53

several collaborative projects for the collection and evaluation of crops of mutual interest.

The ICRISAT genebank is one of the largest repositories for our mandate crops, presently holding 89,117 accessions. These accessions represent the largest collection of germplasm assembled at any one place for our five mandate crops. However, considering the world hectarage of these crops, the present collection is still too small.

Problems of Assembly

We are concerned that often germplasm collection missions are launched when crops are at prime maturity. As a result, the collector may miss early-maturing and late-maturing lines. Therefore, our strategy involves collecting landraces at different times of the year if necessary at the same locations. The success of any germplasm collection mission largely depends on the collectors' knowledge of the crops, their wild relatives, geographical and political accessibility, proper collection strategies, correct sampling procedures, and safe and rapid transfer of the collected material to the genebank.

Conservation

Seed conservation probably started soon after man domesticated crops about 10,000 to 12,000 years ago (Harlan, 1975). Until recent years, crop improvement scientists were not unduly concerned if their collected germplasm samples were lost, as they could easily find and re-collect such seeds (Hawkes, 1981). Now the situation is entirely different; if plant breeders need a ready supply of germplasm, they must rely on man-made genebanks. The maintenance and preservation of landraces in protected gene reserves (*in situ* conservation), though desirable in some specific cases, may not be practical or economical. We do not seem to have any alternative other than to urgently collect and conserve the invaluable germplasm in genebanks.

There are three types of cold stores where germplasm is conserved at ICRISAT: short-, medium- and long-term. All the germplasm accessions of the Institute's mandate crops are now conserved in medium-term (4 °C and about 20% RH) storage. About 500 to 1000 g seed of each accession is dried to approximately 5 to 7% moisture content before it is stored. The type of storage chambers used at ICRISAT, and the general standards and systems of germplasm conservation technology have been described by Mengesha and Prasada Rao (1981) and by IBPGR (1979). Comprehensive reports on viability of seeds, and principles and practices of seed storage are given by Roberts (1974) and Justice and Bass (1978). Long-term cold storage (−20 °C) modules have been installed as part of the ICRISAT genebank and are currently under test. Seed viability is monitored by testing germination in the stored samples. Accessions with less than 85% viability and with critical quantity are rejuvenated. The latest germination tests on conserved seeds showed over 92% viability after almost 8 years in store.

In order to avoid genetic drift during rejuvenation and maintenance, sorghum, which may out-cross, is maintained by selfing at least 20 representative heads (Mengesha and Prasada Rao, 1981). Pearl millet, which is cross-pollinated is maintained by enclosing several heads in a large bag (Appa Rao, 1980). Pigeon pea, which is often cross pollinated mainly by insects, is maintained by enclosing the entire plant or branches in large muslin cloth bags (Remanandan, 1986). Chickpea and groundnut are completely self-pollinated crops, and hence it is not necessary to control pollination. However, in groundnut only those pods which are

attached to the pegs are collected (Ramanatha Rao and Sadasivan, 1985). It must be stressed that only those seeds that are harvested from disease-free plants are conserved in the genebank. Stringent field inspections and laboratory tests are made to ensure storage and distribution of disease- and pest-free seeds.

Diversity

The material collected from various sources is evaluated according to descriptors standardised by ICRISAT and IBPGR in the rainy and post-rainy seasons at ICRISAT Center, Patancheru. Variation in important morphological and agronomic characters is considerable and the range observed in different crops is given in Table 3. The range in chickpea variation was wider in accessions evaluated at Hisar, Haryana than at ICRISAT Center, India (Saxena and Sheldrake, 1980). Likewise, considerable variation was recorded when 343 pearl millet collections were evaluated at five different locations in India, Burkina Faso, and Niger.

Table 3. Variability range in some selected characters of ICRISAT mandate crops evaluated at ICRISAT Center, Patancheru

Characters	Sorghum	Pearl millet	Pigeonpea	Chickpea	Groundnut
Days to 50% flowering	36–199	33–140	55–210	28–96	16-58
Plant height (cm)	55–655	11–475	39-385	16–93	—
Peduncle exsertion (cm)	0–55	−21–+30	—	—	—
Head length (cm)	2.5–71	6–165	—	—	—
Head thickness (mm)	10–290	10–64	—	—	—
Number of tillers	1–15	1–210	—	—	—
Stalk sugar content (%)	12–38	4.9–19.7	—	—	—
Grain colour	white-dark brown	white-dark purple	white-black	cream-black	off-white-dark purple
Seeds pod	—	—	1.6–7.6	1–2.8	1–5
100-seed mass (g)	0.58–8.56	0.3–1.93	2.8–22.4	4.9–59.4	19.8–121.5
Plant width (cm)	—	—	—	18–70	—
Pods plant	—	—	—	few-168	—
Harvest index (%)	—	—	—	21.9–64.8	—
Seed protein (%)	—	—	12.4–29.5	15.4–30.9	—
Oil content %	—	—	—	—	31.8–53.1

The main purpose in pointing out the range in variation is to underline the importance of germplasm in crop improvement. Although, the conserved variation is very useful, it is considered small as compared to that available in nature. Many remote areas are yet to be explored.

Table 4. Variability range in cultivated groundnut

Characters	Minimum	Maximum	Intermediate
Length of the R. P. branch	<1 cm	>10 cm	Continuous
No. of flowers/inflorescence	1	5	2, 3, 4
Leaflet length	24 mm	86 mm	Continuous
Leaf width	8 mm	41 mm	Continuous
Leaflet L/W	1.53	4.2	Continuous
No. of seeds/pod	1	5 (6)	2, 3, 4
Pod length	11 mm	80 mm	Continuous
Pod width	9 mm	27 mm	Continuous
Seed colour	off white	dark purple	Yellow, shades of tan, shades of red, grey-orange, purple and variegated
Seed length	7 mm	21 mm	Continuous
Seed width	5 mm	13 mm	Continuous
100-seed weight	19.8 g	121.5 g	Continuous
Days to emergence	4	13	Continuous
Days to 50% fls.	16	58	Continuous
Days to maturity	75	>155	Continuous
Oil content	31.8%	53.1%	Continuous

Unfortunately, the continued availability of germplasm in nature can not be guaranteed in view of the alarming genetic erosion that is taking place around the world. A good example of such genetic erosion is the complete absence of Zerazera and Hegari sorghum landraces in the Gezira Province of Sudan, and their replacement by newly bred cultivars (Mengesha and Prasada Rao, 1981), and the once-popular pearl millet landrace 'Gullisita' is now almost extinct in Punjab (Appa Rao *et al.*, 1986).

UTILISATION

The potential of a germplasm sample is largely unknown at the time of its collection. However, we have seen that a number of desirable characters are identified whenever a diverse group of germplasm samples are evaluated and screened. At times, even those lines that show susceptibility to a disease or pest offer a rare source of breeding material for other agronomically desirable traits. For example, sorghum accessions IS 1082, 2122, 2145, 4663, 4664, 5470, 5484, 5566, 18551, and others have been identified as having promising shoot fly (*Atherigona soccata*) resistance. They are, however, susceptible to grain molds. Other sorghum germplasm lines such as IS 620, 621, 5959, 7237, 8219, 9308,

1482, and 11234 have promising grain mold resistance; yet they are usceptible to shoot fly and stem borer (*Chilo* sp). Likewise pigeon pea, CP-7035 has resistance to wilt and sterility mosaic, but it is susceptible o blight. ICP 7065 is resistant to blight, but highly susceptible to both ilt and sterility mosaic. There are many more examples like these which ould have been rejected for one reason, while useful sources are retained or their other traits (Mengesha, 1984).

Much emphasis is presently placed on multilocational evaluation f germplasm. NBPGR is playing a leading role in this work in India. everal thousand germplasm accessions are being jointly evaluated by BPGR and the Genetic Resources Unit of ICRISAT at different ocations. This will enhance the identification and utilisation of new and seful germplasm accessions.

For example, the pearl millet germplasm grow-out at Jodhpur ffered an excellent opportunity to screen under drought stress conditions as the rainfall during the crop season was less than 200 mm. Only arly-maturing lines flowered and produced seeds. The drought stress was o severe that late-maturing and photoperiod-sensitive lines from Sierra eone, Senegal, and Nigeria died before floral initiation. The grow-out as used by breeders wherein ICRISAT breeders selected 18 lines, and illet breeders of the Central Arid Zone Research Institute, Jodhpur, elected 85 promising lines for drought-tolerance.

Considering the worldwide crop improvement programme and in iew of the plant breeders' remarkable success in developing high-yielding ultivars, it is obvious that there are significant advantages associated ith international germplasm exchange. With careful handling, imaginave methods, and more specific research on seed pathogen and pest elationships, man should be able to save his valuable seeds for present nd future use.

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