Indigenous Food Legumes of Asia: Germplasm Conservation, Diversity and Utilization in Crop Improvement

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Abstract

Pigeonpea, chickpea, lentil, urdbean and mungbean are important food legumes indigenous to Asia. A large number of accessions of these crops have been assembled and conserved in the genebanks at ICRISAT; ICARDA; NBPGR, India; NARC, Pakistan; AVRDC, Taiwan; BARI, Bangladesh and NPGRL, Philippines; AVRDC, Taiwan; USDA, USA. The collections have been characterized for morphoagronomic traits and large variation was observed. Several sources of resistance to biotic and abiotic stresses have been identified and 9 pigeonpea and 14 chickpea accessions from ICRISAT and 25 chickpea and 10 lentil accessions from ICARDA have been released as cultivars in different countries. Use of germplasm in breeding programs has been very low due to lack of information on economic traits and size of the collections. Development of core (10% of entire collection) and mini core (about 1% of entire collection) collections of these crops helped in identifying genetically diverse accessions resistant to abiotic and biotic stresses.

INTRODUCTION

Legumes are second only to cereals as a source of human and animal food. Nutritionally, they are rich source of minerals and vitamins, and 2-3 times richer in protein of high biological value than cereal grains. Legumes are of multiple uses like, food, feed, fuel, nitrogen fixing, medicine, fencing, roofing, basket making and soil binder. There are many useful legume species adapt well to a wide range of soils and climate. Among them, pigeonpea [*Cajanus cajan* (L.) Millsp.], chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris* Medicus), urdbean (*Vigna mungo* L. Hepper) and mungbean (*Vigna radiata* (L.) Wilczek), are indigenous to Asia, are very important.

Pigeonpea originated in India is the sixth most important legume crop with seed protein (13-31%) and minerals. It is grown over an area of 4.59 m ha with a production of 3.48 million t and the major area of cultivation is in India, Myanmar, Kenya, Malawi, Uganda, Tanzania, Nepal and Dominican Republic. Chickpea originated in South eastern Turkey is a rich source of protein (12-30%). It is grown over an area of 10.6 million ha, with a production of 8.69 million t, mainly grown in India, Iran, Turkey, Pakistan, Morocco, Algeria, Australia Ethiopia, Mexico, Myanmar, Spain, Syria, Tanzania, and Tunisia. Lentil originating in western Turkey is the rich source of protein (22-32%), vitamin B and minerals (Fe, Zn and Mg). It is grown over an estimated area of 4.01 m ha with a production of 4.06 million t, mainly grown in South Asia, Afghanistan, Ethiopia, Egypt, southern Europe, North Africa, North and Latin America (FAO, 2005). Urdbean or black gram originated in India is a good source of protein and minerals. It is mainly confined to India, Pakistan, Afghanistan, Bangladesh, Philippines and Myanmar. Mungbean or green gram originated in India is a good source for high calories (334 cal/100 g), seed protein (20-33%) and iron (4-6 mg per 100 g). It is an important crop in Central and East Africa, Madagascar, China, Thailand, New Guinea to Northern and Eastern Australia.

Despite of their importance, indigenous legumes remained as an under exploited and under researched crops until recently. In ensuring that the plant breeders will have genetic resources for use in plant breeding programs, assembly, conservation, characterization, evaluation and documentation of plant genetic resources of these crops is essential. Therefore, in this paper, germplasm assembly of five important indigenous legumes, its conservation, diversity in the collections and the utilization of these collections in crop improvement is summarized and discussed.

GERMPLASM ASSEMBLY

Having the responsibility of world repository, R.S. Paroda genebank at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) holds 13,632 and 19,187 accessions of pigeonpea and chickpea germplasm, respectively (Upadhyaya et al., 2005). The genebank at International Centre for Agricultural Research in the Dry Areas (ICARDA) holds 10,119 accessions of lentil germplasm. Efforts for germplasm assembly were reasonably good and systematic in case of pigeonpea, chickpea and lentil but the germplasm enrichment in urdbean and mungbean had been limited, currently fragmented and scattered in different countries/centers and needs to be centralized (Table 1) (IBPGR, 1989).

CONSERVATION AND MAINTENANCE

Germplasm is conserved to ensure continued availability of healthy seeds. Controlled environmental conditions prolong the germinability of conserved seeds and minimize the need for regeneration, which is expensive and involves risk to genetic integrity of accession. Different centers are conserving the germplasm of the legume crops under study, in different storage conditions depending upon the facilities and resources available. At the ICRISAT genebank, pigeonpea and chickpea germplasm seeds are conserved in short-term (20°C temperature, 35% RH), medium-term (4°C temperature, 30% RH–as active collection) and long-term storage (-20°C temperature, as base collection).

Seed viability and quantity of conserved germplasm are monitored at regular intervals. The accessions that reach critical level for seed viability (<85% viability) and/or seed quantity (<¼ of total quantity) are regenerated without deviation in accession integrity. Regeneration of germplasm, particularly of often cross-pollinating species like pigeonpea is the most crucial process in genebank management as it has direct effect on the genetic integrity of the accessions. At ICRISAT, pigeonpea accessions are regenerated under bee proof pollination control cages. Being self-pollinating crops, chickpea, lentil, urdbean and mungbean do not require any pollination control while regeneration.

CHARACTERIZATION AND EVALUATION

Germplasm collection is of little value unless it is characterized, evaluated and documented properly to utilize in crop improvement. A multi-disciplinary approach is required to have complete characterization and evaluation information on the accessions. About 95% of cultivated pigeonpea and chickpea collection have been characterized. To realize the full potential of the accessions for agronomic performance and facilitate the selection of genotypes by researchers, sets of selected accessions were evaluated for important agronomic characters at different locations in various countries.

GEOGRAPHICAL PATTERNS OF DIVERSITY IN COLLECTIONS

At ICRISAT, in pigeonpea, maximum range of variation for quantitative traits was in accessions from Maldives, Sri Lanka and southern India and minimum in accessions from Europe and Oceania (Table 2). Shannon Weaver diversity index (H`) indicates that the accessions from Indonesia, Philippines and Thailand had the highest pooled H` for qualitative traits (0.349+0.059) and accessions from Africa for quantitative traits (0.613+0.006). African accessions also had highest pooled H` (0.464+0.039) and from Oceania had the lowest pooled H` (0.337+0.037) (Upadhyaya et al., 2005). Large numbers of resistance/ promising sources of pigeonpea accessions were identified for biotic and abiotic stresses (Table 3).

In chickpea, South Asia region contained the largest range of variation for all the traits (Table 2). The H` values varied in different regions for different traits. Cluster analysis based on first three PC scores (90.9% variation) delineated two regional clusters consisting of Africa, South and South-east Asia in the first cluster; and the Americas, Europe, West Asia, Mediterranean and East-Asia in the second cluster (Upadhyaya, 2003). The analysis revealed the need to secure more entries from Mediterranean countries. Screening of ICRISAT chickpea germplasm resulted in the identification of several resistant/promising sources for abiotic and biotic stresses (Table 3).

In Lentil, genetic stocks showing resistant to wilt (Singh, 1991), collar rot (Mohammad and Kumar, 1986) rust (Singh and Sandhu, 1988), blight (Sugha et al., 1991), drought (Hamdi and Erskine, 1996) and salinity (Ashraf and Waheed, 1990) have been identified. Large variation was reported for various traits in the collection of urdbean (Singh et al., 2000). Screening of urdbean germplasm resulted in several resistant sources for yellow mosaic virus (Asthana and Chandra, 1995) and powdery mildew (Kaushal and Singh, 1989). Though the collections are scattered, several workers have reported wide variability for various morphoagronomic traits in mungbean. Resistant sources for mosaic virus (Mohanty et al., 1998), bacterial leaf spot (Deshmukh et al., 1999), and thrips (Chhabra and Malik, 1992) were identified in mungbean.

DOCUMENTATION

Both passport and characterization data of ICRISAT's pigeonpea and chickpea collections and those of ICARDA's lentil collection are available in the SINGER database, which can be browsed through http://SINGER.GRINFO.NET. Germplasm catalogs were published using the passport and characterization data for chickpea, pigeonpea, Kabuli chickpea, lentil, urdbean and mungbean.

GERMPLASM DISTRIBUTION AND UTILIZATION

ICRISAT genebank provided 66,340 samples of pigeonpea and 120,816 samples of chickpea to the bonafide users of germplasm (Upadhyaya et al., 2006c). At ICRISAT, to enhance the utilization of pigeonpea and chickpea germplasm, characterized almost all cultivated accessions, initiated linkages and tested sets of selected accessions at different locations in India and countries in Africa and Americas, organized field days facilitating the selection of material by researchers. Developed trait-specific genepools, core collection (10% of entire collection) of pigeonpea (Reddy et al., 2005), chickpea (Upadhyaya et al., 2001), lentil (Tullu et al., 2001), and mungbean (Bisht et al., 1998) and mini core collections of pigeonpea and chickpea (1% of entire collection) (Upadhyaya and Ortiz 2001; Upadhyaya et al., 2006). Using the core and mini core approaches, scientists at ICRISAT have identified trait specific germplasm in chickpea (tolerant to drought and salinity, disease resistance, high yield, early maturity, large seed size in Kabuli) and pigeonpea (salinity tolerance, disease resistance, early maturity, high yield, large seed size, high harvest index) for use in breeding programs.

DEVELOPMENT OF COMPOSITE COLLECTIONS

As part of the Generation Challenge Program (GCP) of Consultative Group on International Agricultural Research (CGIAR), which aims to explore the genetic diversity of global germplasm collections, scientists developed composite collections of chickpea (3000 accessions, and pigeonpea (1000 accessions), at ICRISAT and that of lentil (1000 accessions) at ICARDA, representing the entire collection, ecologically, taxonomically and phenotypically. These sets were genotyped using 50 SSR markers in chickpea, 20 SSR markers in pigeonpea and 30 SSR markers in lentil to determine population structure and develop a reference sample of 300 accessions in all the three crops for further evaluation and identification of promising sources against drought and important agronomic traits.

The evaluation of elite germplasm resulted in the release of nine pigeonpea accessions and 19 chickpea accessions as varieties either directly or as selections, in different countries (Table 4). About 25 accessions of chickpea and 10 accession of lentil from the ICARDA genebank were released in 14 and 7 countries, respectively. Majority of the lentil, urdbean and mungbean cultivars released in different countries are mostly selections within the landraces. To further enhance the utilization of these crops, collections should be consolidated and core and mini-core collections are to be developed and evaluated extensively to identify useful germplasm for effective utilization of genetic resources in crop improvement programs of these under explored crops.

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Tables

Table 1. Major germplasm holdings of important legumes indigenous to Asia.

Institute	Pigeonpea	Chickpea	Lentil	Urdbean	Mungbean
Bangladesh Agricultural Research Institute, Dhaka, Bangladesh		666	798	339	498
Genetic Resources Unit, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India	13632	19187			
National Bureau of Plant Genetic Resources, New Delhi, India	7488	14566	2212	1429	1485
Genetic Resources Laboratory, National Agricultural Research Centre, Islamabad, Pakistan		2584	640	479	627
National Plant Genetic Resources Laboratory, Institute of Plant Breeding , Laguna, Philippines	433	404			5736
Centro de Investigacion y Desarollo Agrario de Cordoba , Cardoba, Spain		2184			
International Centre for Agricultural Research in the Dry Areas, Aleppo, Syria		12032	10119		
AVRDC-The world Vegetable Centre, P.O. Box 42, Shanhua, Tainan, Taiwan				478	5678
Regional Plant Introduction Station (W-6), Washington State University, Pullman, Washington, USA		4662	1422		
National Seed Storage Laboratory, Colorado State University, Colorado, USA		2031	617		208
Regional Plant Introduction Station (S-9), Georgia, USA				277	3864
N.I. Vavilov All-Union Scientific Research Institute of Plant Industry, Leningrad, USSR (former)		2293			

Source: IBPGR, 1989

Table 2. Range of variation in pigeonpea and chickpea germplasm assembled at ICRISAT genebank.

Character	Mean	Minimum	Maximum	Character	Mean	Minimum	Maximum
Pigeonpea				Chickpea			
Days to 50% flowering	133.5	52	237		62.5	31	107
				Days to 50% flowering			
Days to 75% maturity	192.1	100	299	Days to maturity	115.9	84	169
	177.9	39	310	Flowering duration (days)	34.1	13	75
Plant height (cm)							
Primary branches/plant (no.)	13.52	1.1	107		37.7	14	105
				Plant height (cm)			
Secondary branches/plant (no.)	31.3	0	145.3		40	13	124
				Canopy width (cm)			
Tertiary branches/plant (no.)	8.8	0	218.7	Number of pods per plant	40.4	2	251
	287.3	9.3	1819.3	Number of seeds per pod	1.2	1	3.2
Pods per plant (no.)							
Seeds per pod	3.72	1.6	7.2	Seed yield (kg/ha)	1221	70	5130
100-seed weight (g)	9.28	2.7	25.8	100-seed weight (g)	16.8	3.8	65.4
	21.25	13	30.8	Seed protein content (%)	19.5	8	29.6
Seed protein (%)							
Shelling percentage	60.66	5.8	93.6				
Seed yield/plant (g)	97.37	1	720				
Harvest index (%)	21	0.6	73.9				

Table 3. Summary of pigeonpea and chickpea germplasm screening at ICRISAT genebank.

Stress	No. of accessions screened	Promising sources identified	Stress	No. of accessions screened	Promising sources identified
Pigeonpea			Chickpea		
Wilt	11707	107	Wilt	15000	1136
Sterility mosaic disease	13201	397	Ascochyta blight	3000	192
Phytophthora blight	7669	152	Botrytis gray mold	2400	49
Stem canker	-	26	Colletotrichum blight	9000	72
Alternaria blight	-	25	Pod borer	16346	20
Pod borer	10090	27	Drought	1000	11
Pod fly	10090	21	Cold	1000	16
Pod borer and pod fly	10090	6	Salinity	1000	4
Nematodes	6700	12			
Drought	-	7			
Water logging	-	5			
Salinity	-	29			

Table 4. ICRISAT's pigeonpea and chickpea germplasm released as varieties.

Accession Number	Country of origin	Country of release	Name of release	Year of release
Pigeonpea				
ICP 997	India	Nepal	Rampur Rhar	1992
ICP 7035	India	Fiji	Kamica	1985
ICP 7035	India	Philippines		1989
ICP 7035	India	China	Guimu 4	2003
ICP 8863	ICRISAT	India	Maruti	1985
ICP 9145	Kenya	Malawi	Nandolo wa Nswawa	1988
ICP 9905	India	Venezuela	La Cerrera	1991
ICP 11384	Nepal	Nepal	Bageshwari	1992
ICP 11916	India	Venezuela	Aroa	1991
ICP 13829	Granada	Venezuela	Cerro Pelon	1991
ICP 14770	ICRISAT	India	Abhaya	1989
Chickpea				
ICC 237	India	Oman	ICC 237	1988
ICC 552	India	Myanmar	Yezin 1	-
ICC 3274	Iran	Bangladesh	Bari Chhola 7	1999
ICC 4923	India	India	Jyothi	1978
ICC 4944	India	Myanmar	Keyhman	-
ICC 4951	India	Myanmar	ICC 4951	-
ICC 4998	India	Bangladesh	Bino-Sola 2	1994
ICC 6098	India	Nepal	Radha	1987
ICC 8521	Italy	USA	Aztee	-
ICC 8649	Afghanistan	Sudan	Shendi	1987
ICC 11879	Turkey	Syria	Ghab 1/ -	1982
ICC 11879	Turkey	Turkey	-	1986
ICC 11879	Turkey	Algeria	-	1988
ICC 11879	Turkey	Morocco	-	1988
ICC 13816	USSR	Algeria	Yialousa	1984
ICC 13816	USSR	Italy	Sultano	1987
ICC 13816	USSR	Syria	Ghab 2	1986
ICC 13816	USSR	Cyprus	-	-
ICC 14880	India	Australia	Hira	1997
ICC 14911	USSR	Turkey	-	1986
ICC 14911	USSR	Morocco	-	1987