The Wild Genepool of Pigeonpea at ICRISAT Genebank - Status and Distribution

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Wild pigeonpea genepool is a promising source for various biotic and abiotic stress resistances, and important agronomic and nutritional traits. The genebank at ICRISAT, Patancheru, India, conserves 13,771 accessions of pigeonpea from 74 countries, including 555 accessions of wild relatives belonging to 66 species of six genera from 41 countries. Out of 11 genera now recognized in *Cajaninae*, only six are available at ICRISAT genebank. Of the 32 species recognized in genus *Cajanus,* ICRISAT genebank holds a total of 213 accessions of 19 species and *C. scarabaeoides* has largest number of accessions (102 accessions). Genebank has 303 accessions of genus *Rhynchosia* represented by 33 species and largely represented by *R. minima* (186 accessions). Genus *Paracalyx* has two accessions of one species; genus *Dunbaria* has 12 accessions of two species; genus *Eriosema* has seven accessions of three species and genus *Flemingia* is represented by 18 accessions of eight species.

Key Words: *Cajanus,* Genepool, Germplasm, *Rhynchosia,* Wild species

Introduction

Pigeonpea (*Cajanus cajan* (L.) Millspaugh) is one of the important grain legume crops of tropics and subtropics. Because of its multiple uses, pigeonpea cultivation is extended to about 82 countries as a field or as backyard crop. Due to high seed protein content (up to 25%), pigeonpea is an important protein source for the vegetarian population especially, in the Indian sub-continent. Considerable progress in pigeonpea improvement has been made by using variability within the cultivated species. However, the crop still suffers from several biotic stresses like pod borer (*Helicoverpa armigera* Hubner), podfly (*Melanagromyza obtusa* Mall), sterility mosaic disease (SMD), wilt (*Fusarium udum* Butler) and phytophthora blight (*Phytophthora drechsleri* Tucker); and abiotic stresses such as salinity and water logging conditions. Many wild relatives (WR) including those of pigeonpea have survived drought, floods, extreme heat and cold, and have developed resistance to various biotic and abiotic stresses. Wild relatives are more important when they possess traits of agronomic importance in addition to biotic and abiotic stress resistance especially, those that can be hybridized easily with cultivated species. Despite their importance, the wild relatives have not received due attention from germplasm collectors and plant breeders, and remain under-represented, accounting for less than two percent of the global germplasm collections of major food crops (Kameshwara Rao, 2003). The knowledge on existing collections of wild relatives is meager and poorly documented. Therefore, the present study was aimed at reviewing the world collection of pigeonpea wild relatives conserved at the genebank of International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India, for their geographical distribution, useful traits and crossability relationships to enhance their utilization in pigeonpea improvement.

Materials and Methods

ICRISAT genebank serves as world repository for pigeonpea germplasm and conserves 13,771 accessions originated in 74 countries, including 555 accessions of wild relatives. Wild accessions introduced from different sources and collected in different countries were identified and by using passport information, summarized belonging to 66 species of six genera. Number of accessions in each species, genepool affinity, geographical distribution, identification of promising species and studies on crossability relationships were discussed for enhanced utilization of wild relatives' germplasm in pigeonpea improvement.

Results and Discussion

Germplasm Assembly

The wild relatives of many crop plants including those of pigeonpea are disappearing at an alarming rate due to rapid urbanization, shifting cultivation, forest fires, climate change, natural calamities, over grazing etc. (Upadhyaya and Gowda, 2009). The genebank at ICRISAT,

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Patancheru, India assembled and is conserving 13,771 accessions of pigeonpea from 74 countries including 555 accessions of wild relatives belonging to 66 species of six genera, from 41 countries (Table 1). The assembly of wild relatives' germplasm includes introductions from different organizations and the germplasm collected by ICRISAT in collaboration with NARS partners, universities, NGOs, Bioversity International (formerly IPGRI) *etc.,* by launching collection missions in priority areas. A total of 314 accessions of wild relatives were introduced from various organizations located in different countries. Australia was the major donor providing 254 accessions that originated in different countries. The collection strategy for wild species involves identification of geographic distribution of species, precise location, time of fruiting etc., which need to be gathered from different herbaria and through correspondence. As the wild relatives are uncommon in natural vegetation and location data are often old and not precise, hence, it is always not feasible to follow the collection strategy recommended for the cultivated species (Remanandan, 1981). ICRISAT and partners have launched a total of 216 germplasm collection missions in 62 countries for its mandate crops and their wild relatives including those of pigeonpea and collected 241 samples of pigeonpea wild relatives during 40 collection missions in nine countries. India being the primary center of diversity for pigeonpea resulted in 154 accessions from 26 collection missions.

The assembled species are summarized by number of accessions and traits of importance in Table 1. Out of 11 genera now recognized in *Cajaninae*, only six are available at ICRISAT genebank. Among six genera, *Cajanus* and *Rhynchosia* have largest number of accessions. Of the 32 species recognized in genus *Cajanus,* the cultivated species (*Cajanus cajan)* and 19 wild species are assembled at ICRISAT genebank. Out of 213 accessions of all these wild species, *C. scarabaeoides* is represented by largest number of accessions (102 accessions). Genus *Rhynchosia* represented by 33 species has 303 accessions largely represented by *R. minima* (186 accessions). The remaining 117 accessions belong to 32 other species. Genus *Paracalyx* has only one species with two accessions; *Dunbaria* has two species with 12 accessions; *Eriosema* has three species with seven accessions and genus *Flemingia* represented by eight species with 18 accessions. (Table 1). Species classification for three accessions of genus *Flemingia* and seven accessions of genus *Rhynchosia* is not yet known. The summary of wild relatives' germplasm at ICRISAT genebank indicates wide taxonomical gaps in the collection and urgency of filling these gaps.

All the species assembled at ICRISAT genebank are seed producing and are conserved as active collection in medium-term cold store maintained at 4ºC and 35% RH. Species with critical seed quantity are multiplied by growing in the botanical garden. The passport information on the collection is available at http://www.icrisat.org/ICRISAT.crops.htm. ICRISAT genebank has served as a major source for pigeonpea wild relatives' germplasm. Limited seeds of all in-trust accessions with FAO are available under Standard Material Transfer Agreement (SMTA) of the International Treaty for research and utilization globally. So far, the genebank has provided 4,633 seed samples of 56 species for research use in 31 countries.

Geographical Distribution

The geographical distribution of different species is presented in Table 2. Asian countries are the predominant source and accounted for a total of 285 accessions belonging to 50 species of six genera in the collection. India is represented by 201 accessions of 35 species belonging to six genera. Oceania was another important region for pigeonpea wild relatives accounting for 78 accessions of 13 species and three genera. Australia alone is represented by 73 accessions of 13 species of three genera. Twelve African countries, particularly, the eastern and southern Africa have accounted for 69 accessions of 16 species belonging to *Dunbaria, Eriosema* and *Rhynchosia*. Mexico is represented by 59 accessions of six species of *Rhynchosia*. Eight countries each of Central America and South America contributed 61 accessions belonging to 24 species of three genera and United Kingdom represented as a donor for one *Cajanus* accession.

Promising Sources

The collection of pigeonpea wild relatives at ICRISAT genebank has not been characterized and evaluated systematically, which involves participation of multidisciplinary scientists and additional resources. However, screening and evaluation of limited species by researchers indicated wild pigeonpea genepool as a promising source for various biotic and abiotic stresses in addition to possessing some important agronomic traits (Reddy *et al*., 2000). The major constraints

Table 1. Summary of pigeonpea wild relatives' germplasm assembled at the ICRISAT genebank, Patancheru, India.

Genus	Species	No. of accs.	Genepool*	Traits of importance	References
Cajanus	*acutifolius* (F.v. Muell.) van der Maesen	12	2	Drought and salinity tolerant	Remanandan (1981); Srivastava *et al*. (2006)
	albicans (W. & A.) van der Maesen	20	2	Resistance to SMD, alternaria blight; drought and salinity tolerance, high seed protein (> 30%), and crossable with pigeonpea	Pundir and Singh (1985a); Reddy *et al*. (2000)
	cajanifolius (Haines) van der Maesen	5	2	Salinity tolerant, tolerant to pod borer, podfly and pod wasp, source for A5 cytoplasm and crossable with pigeonpea	Singh *et al*. (1990); Pundir and Singh (1985a); Reddy *et al.* (2000); Sharma *et al*. (2006)
	cinereus (F.v. Muell.) F.v. Muell.	1	–		
	confertiflorus F.v. Muell.	1	3		
	crassus (Prain ex King) van der Maesen	10	3	Source for A3 Cytoplasm	
	elongatus (Benth.) van der Maesen	1	3		
	goensis Dalz.	1	3	High seed number per pod	van der Maesen, (1986)
	lanceolatus (W.V. Fitzg.) van der Maesen	1	2		
	latisepalus (Reynolds & Pedley) van der Maesen	1	2		
	lineatus (W. & A). van der Maesen	10	2	Resistance to SMD and alternaria blight; drought tolerance, early flowering, source for A6 cytoplasm and crossable with pigeonpea	Pundir and Singh (1985a); Reddy *et al*. (2000)
	marmoratus (R. Br. Ex Benth.) F. von Mueller	2	3		
	mollis (Benth.) van der Maesen	8	3	High seed protein content (33.4%) and high seed number per pod	Remanandan (1990); van der Maesen (1986)
	platycarpus (Benth.) van der Maesen	17	3	Resistance to phytophthora and alternaria blight; salinity tolerance; annuality, rapid seedling growth, photoperiod insensitivity, extra early flowering and maturity, high harvest index; high seed protein (27-31.6%), high cystine + methionine (> 29%) and a source for A7 cytoplasm	Reddy *et al*. (2000); Srivastava *et al*. (2006)
	reticulatus (Dryander) F.v. Muell.	8	2	Hardy, fire-tolerant, resistant to pod borer, high seed protein (33%) and a source for A8 cytoplasm	Akinola *et al*. (1975); Reddy *et al*. (2000)
	rugosus (W and A) van der Maesen	6	3		
	scarabaeoides (L.) Thouars	102	2	Early flowering, resistance to wilt, sterility mosaic disease (SMD), phytophthora blight (both for P2 and P3 isolates), alternaria blight, pod borer, podfly, pod wasp, cyst nematode, and possesses combined resistance to diseases and insects; water logging tolerance; high seed protein (> 28%), source for A2 cytoplasm and crossable with pigeonpea	Pundir and Singh (1985a); Reddy *et al*. (2000)

** 2=Secondary genepool, 3=Tertiary genepool, 4=Quaternary genepool*

Genus	Species	No. of accs.	Genepool	Traits of importance	References
	sericeus (Benth. Ex Bak.) van der Maesen	4	2	Resistance to SMD, phytophthora, and alternaria blight; pod borer, podfly, pod wasp; drought and salinity tolerance ; high seed protein content (> 29%), source for A1 cytoplasm and crossable with pigeonpea	Remanandan (1990); Sharma, (2006); Upadhyaya (2006)
	trinervius (DC.) van der Maesen	3	2	Crossable with pigeonpea	Pundir and Singh (1985a); Reddy *et al*. (2000)
	Total	**213**			
Dunbaria	*ferruginea* Wight & Arn	7	4	Salinity tolerant	Singh *et al*. (1990)
	heynei Wight & Arn	5	4	Green manure	Arora and Chandel (1972)
	Total	**12**			
Eriosema	*ellipticum* Wel. Ex Beker	1	4	Medicinal use	Abbot and Lowore (1995)
	glomeratum (Guill. & Perr.) Hook. f	1	4		
	sporaleoides (Lam.) G. Don.	2	4		
	unknown	3	4		
	Total	**7**			
Flemingia	*bracteata* Roxb.	2	4		
	involucrate Benth.	1	4		
	macrophylla Benth.	6	4		
	nana Roxb.	1	4		
	paniculata Benth.	1	4		
	semialata Roxb.	1	4		
	stricta Roxb.	1	4		
	strobilifera (L.) W.T. Aiton	5	4	Cover crop and medicinal use	Ambasta (1986)
	Total	**18**			
Paracalyx	*scariosa* Roxb.Ali.	2	4		
	Total	**2**			
Rhynchosia	*americana* (Houst. Ex Mipp.) M.C. Metz.	1	4		
	aurea (Willd.) DC.	8	4		
	bracteata Baker	6	4	Tolerant to pod borer, podfly and pod wasp	Sharma (2006)
	burkartii Fortunato	1	4		
	cana (Willd.) DC.	6	4		
	candida (Hiern) Torre	1	4		
	caribaea (Jacq.) DC.	1	4		
	cyamosperma	2	4		
	densiflora (Roth) DC.	5	4		
	edulis Griseb.	9	4		
	filipes Benth.	2	4		
	heynei Wight & Arn.	1	4		

Genus	Species	No. of accs.	Genepool	Traits of importance	References
	himalensis Benth. Ex Baker	1	4		
	hirta (Andrews) Meikle & Verdc.	3	4		
	kilimandscharica Harms	1	4		
	longiracemosa M. Martens & Galeotti	2	4		
	malacophylla (Spreng.) Bojer	1	4		
	micrantha (Harms)	5	4		
	minima (L.) DC.	186	4	Medicinal use and pasture	Morris (1999)
	pyramidalis (Lam.) Urb.	1	4	Narcotic properties	Farnsworth *et al*. (1967)
	reticulata (Sw.) DC.	1	4	Early flowering, photoperiod insensitivity, protease inhibitor	Reddy *et al*. (2000)
	rothii Benth. Ex. Aitch	11	4	High seed protein content	Remanandan (1981)
	rufescens (Willd.) DC.	7	4		
	schimperi Bioss.	2	4		
	senna Gillies ex. Hook.	2	4		
	suaveolens (L.f.) DC.	2	4		
	sublobata (Schumach.)	9	4		
	totta (Thumb.) DC.	11	4		
	velutina Wight & Arn	1	4		
	venulosa (Hiern) K. Schum.	1	4		
	verdcourtii Thulin	3	4		
	viscidula Steud.	2	4		
	viscose (Roth) DC.	1	4		
	Unknown	7			
	Total	**303**			
	Grand Total	**555**			

to pigeonpea production among the insect pests are pod borer and podfly. Among the diseases, fusarium wilt, sterility mosaic and phytophthora blight are economically important. Sources of resistance identified by different researchers for various biotic and abiotic stresses and agronomic traits in different species include *C. scarabaeoides* for wilt; *C. albicans, C. lineatus, C. scarabaeoides, C. sericeus* and *C. crassus* var. *crassus* for sterility mosaic disease (Reddy *et al*., 2000; Lava Kumar *et al*., 2005); *C. platycarpus, C. scarabaeoides* and *C. sericeus* for phytophthora blight; *C. albicans, C. lineatus, C. platycarpus, C. scarabaeoides* and *C. sericeus* for alternaria blight (Reddy *et al*., 2000); *C. albicans, C. scarabaeoides, C. sericeus, C. reticulatus* and *R. bracteata* for pod borer, podfly and pod wasp (Sharma, 2006); *C. scarabaeoides*, *R. aurea*, *R. minima* and *R. rothii* for nematodes (*Rotylenchulus reniformis*) (Sharma *et al*., 1993); *C. acutifolius, C. albicans, C. lineatus* and *C. sericeus* for drought (Reddy *et al*., 2000); *C. acutifolius, C. albicans, C. cajanifolius, C. platycarpus, C. scarabaeoides, C. sericeus* and *D. ferruginea* for salinity (Srivastava *et al*., 2006); *C. scarabaeoides* for water logging; *C. lineatus* for cleistogamy (Saxena *et al*., 1992) and *C. reticulatus* var *grandifolius* for fire tolerance (Reddy *et al*., 2000) (Table 1). *C. platycarpus* and *C. scarabaeoides* for early flowering; *C. platycarpus* and *R. reticulata* for photoperiod insensitivity (Reddy *et al*., 2000);

Table 2. Geographical distribution of pigeonpea wild relatives germplasm assembled at the ICRISAT genebank, Patancheru, India

Region	Country	No. of accessions	Species
Africa	Angola	1	*R. candida*
	Botswana	3	*R. minima* and *R. totta*
	Kenya	5	*R. edulis, R. micrantha, R. rothii, R. totta* and *R. velutina*
	Malawi	4	*E. ellipticum, Eriosema* sp. and *R. sublobata*
	Mali	4	*R. minima*
	Mozambique	1	*R. totta*
	Namibia	5	*R. minima* and *R. totta*
	Senegal	1	*E. glomeratum*
	South Africa	15	*R. cyamosperma, R. densiflora, R. minima, R. sublobata, R. totta* and *R. venulosa*
	Tanzania	13	*R. aurea, R. densiflora, R. micrantha, R. minima, R. sublobata, R. verdcourtii* and *D. ferruginea*
	Zambia	7	*R. minima* and *R. sublobata*
	Zimbabwe	10	*R. minima, R. sublobata* and *R. totta*
Asia	China	1	*R. minima*
	India	201	*C. albicans, C. cajanifolius, C. crassus, C. elongatus, C. goensis, C. lineatus, C. mollis, C. platycarpus,, C. rugosus, C. scarabaeoides, C. sericeus, C. trinervius, D. ferruginea, D. heynei, Eriosema* sp., *F. macrophylla, F. nana, F. semialata, F. stricta, F. strobilifera, P. scariosa, R. aurea, R. bracteata, R. cana, R. cyamosperma, R. densiflora, R. filipes, R. heynei, R, himalensis, R. hirta, R. minima, R. rothii, R. rufescens, R. schimperi, R. suaveolens,* and *R. viscidula*
	Indonesia	36	*F. bracteata, F. involucrata, F. strobilifera, R. minima, R. rufescens, Rhynchosia* sp. and *C. scarabaeoides*
	Myanmar	8	*C. crassus, C. scarabaeoides, F. paniculata* and *R. bracteata*
	Oman	3	*R. kilimandscharica* and *R. minima*
	Pakistan	1	*Rhynchosia* sp.
	Philippines	2	*C. scarabaeoides*
	Sri Lanka	33	*C. albicans, C. rugosus, C. scarabaeoides, C. trinervius, R. cana, R. viscose* and *Rhynchosia* sp.
Europe	United Kingdom	1	*C. scarabaeoides*
North America	Mexico	59	*R. americana, R. caribaea, R. edulis, R. longeraemosa, R. minima, R. pyramidalis* and *Rhynchosia* sp.
Central America	Antigua and Barbuda	4	*R. minima*
	Belize	2	*R. longeraemos* and *R. minima*
	Costa Rica	1	*R. minima*
	Cuba	6	*R. minima*
	Honduras	1	*R. minima*
	Nicaragua	4	*R. minima*
	Panama	2	*R. minima* and *R. reticulata*
	Trinidad and Tobago	1	*F. bracteata*
South America	Argentina	8	*R. burkartii, R. edulis, R. minima* and *R. senna*
	Bolivia	8	*R. edulis* and *R. minima*
	Brazil	10	*R. edulis* and *R. minima*
	Colombia	3	*R. minima*

Region	Country	No. of accessions	Species
	Ecuador	1	*R. minima*
	Paraguay	5	*R. edulis* and *R. minima*
	Peru	2	*R. minima*
	Venezuela	3	*R. minima*
Oceania	Australia	73	*C. acutifolius, C. cinereus, C. confertiflorus, C. lanceolatus, C. latisepalus, C. marmoratus, C. reticulatus, C. scarabaeoides, C. sericeus, E. sporaleoides, R. edulis, R. minima* and *R. viscidula*
	Fiji	2	*C. scarabaeoides*
	Papua New Guinea	3	*C. reticulatus* and *R. minima*
No information		2	*C. scarabaeoides* and *R. malacophylla*

C. aromaticus, *C. goensis* and *C. mollis* for high seed number per pod (van der Maesen, 1986) and *C. scarabaeoides* for high pod setting (74%) (Upadhyaya, 2006) are the important sources for agronomic traits. The highest seed protein content in the entire collection of cultivated pigeonpea was 30.8% (Remanandan, 1990) and evaluation of different species for seed protein content revealed that *C. lineatus* (34.2%), *C. crassus* (33.8%), *C. cajanifolius* (33.6%), *C. mollis* (33.4%), *C. platycarpus* (33.3%), *C. scarabaeoides* (up to 34%) and *C. albicans* (32.5%) as the best sources (Reddy *et al*., 1997; Reddy *et al*., 2000) (Table 1). Genetic male sterility is available in *C. cajanifolius* (van der Maesen, 2006). Most of the *Cajanus* species are palatable to cattle and goats and many wild species of pigeonpea are useful in rearing lac insects. Some wild species of pigeonpea were found as the sources of cytoplasmic and genetic male sterility system (CGMS). *C. sericeus* for A1 cytoplasm (Ariyanayagam *et al*., 1995; Saxena *et al*., 1996), *C. scarabaeoides* for A2 cytoplasm (Tikka *et al*., 1997; Saxena and Kumar, 2003), *C. volubilis* for A3 cytoplasm (Wanjari *et al*., 2001), *C. cajanifolius* for A4 cytoplasm (Saxena *et al*., 2008), *C. cajan* for A5 cytoplasm, *C. lineatus* for A6 cytoplasm, *C. platycarpus* for A7 cytoplasm and *C. reticulatus* for A8 cytoplasm are the known sources of CGMS cytoplasm (Saxena *et al*., 2010). Wild relatives of pigeonpea offered avenues for the development of CGMS system, which led to development of hybrids, a major shift in pigeonpea improvement work.

Crossability Relationships

The main efforts of crossability studies have been interspecific hybridization with pigeonpea. Depending upon the crossability relationships, Harlan and de Wet (1971) placed all species which intercross readily to produce fertile hybrids in to the primary genepool. All cultivated pigeonpeas (*Cajanus cajan)* are included in primary genepool. Species such as *C. acutifolius*, *C. albicans, C. cajanifolius, C. lanceolatus, C. latisepalus, C. lineatus, C. reticulatus, C. scarabaeoides, C. sericeus* and *C. trinervius,* which produce partially fertile hybrids with the cultivated species are placed in secondary genepool. *C. cajanifolius*, which has close affinity to cultivated pigeonpea placed in this genepool is the progenitor of cultivated pigeonpea (Mallikarjuna *et al*., 2011). Tertiary genepool comprises of the all *Cajanus* species, which are not crossable with cultivated species or crossable by using biotechnology tools. Wild species placed in the quaternary genepool belong to genera such as *Flemingia, Rhynchosia, Dunbaria, Eriosema, Paracalyx, Adenodolichos, Bolusafra, Carissoa, Chrysoscias, Baukea* (Mallikarjuna *et al*., 2011) (Table 1). Limited attempts to cross *Rhynchosia* and *Dunbaria* species with *Cajanus cajan* so far have not been successful. Reddy *et al*. (1981) reported that six species (*C. lineatus, C. sericeus, C. scarabaeoides var. scarabaeoides, C. albicans, C. trinervius* and *C. cajanifolius*) cross with cultivated pigeonpea. Pundir and Singh (1985a) reported the crossability of *C. albicans*, *C. cajanifolius*, *C. lineatus, C. scarabaeoides* and *C. trinervius* with cultivated pigeonpea. Within the genus *Cajanus*, *C. lineatus* crossed with *C. albicans* and *C. scarabaeoides* with *C. sericeus*. Three species, (*C. platycarpus*, *C. volubilis* and *R. rothii*) did not cross with any other species. Biosystematic studies encompassing morpho-cytological and electrophoretic analysis of *Cajanus cajan*, seven species of *Cajanus* and one of *Rhynchosia* revealed that *C. cajanifolius* is closest to *C. cajan*, followed by *C. lineatus, C. scarabaeoides, C. sericeus, C. albicans, C. volubilis, C. platycarpus* and *R. rothii*, in that order (Pundir and Singh, 1985b). Tissue culture and embryo

rescue techniques have provided an opportunity for the utilization of tertiary genepool in breeding programmes. Hybrids between *C. platycarpus* and cultivated pigeonpea have been obtained by using embryo rescue technique followed by chromosome doubling through colchicine treatment (Mallikarjuna *et al*., 2006).

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