GERMPLASM COLLECTION, EVALUATION AND UTILIZATION

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1. INTRODUCTION

Crop improvment is based on genetic variation, in the frist place variation present in nature; both cultivated and wild and to a limited extent on variation created by induced mutation. The word germplasm covers both the collective genetic resources of a crop (or animal), as well as the genetic material in the cells. Plant breeders have always relied on germplasm collections, and often their work was most successful when the collection at their disposal included many diverse samples from a wide range of origins. Crop germplasm evolved through recombination and natural mutation, and has been subjected to selection pressures under domestication.

Up to about 1970 the notion that germplasm was in danger of being replaced by uniform, high-yielding cultivars, was not widespread although individual scientists have expressed this view since the early forties. Since then (Frankel and Bennett, 1970; Frankel and Hawkes, 1975; Harlan, 1975) more and more scientists have become aware that conservation and evaluation of all landraces (traditional cultivars) is a pressing need to allow genetic manipulation in the future. Once a single successful cultivar reaches farmers, it may replace a wide range of genotypes grown in an area, making the cultivar vulnerable to new races of diseases and to pest epidemics.

The world now has a network of genetic resources collections (Plucknett *et al.* 1983) covering most of the important food crops. Not all collections are yet safely stored, but both availability of seeds and commitment to preservation are hopeful for the future. The International Agriculural Research Institutes play an important role in collection, maintenance, evaluation, and distribution of several important food crops. The world pigeonpea collection [*Cajanus cajan* (L.) Millsp. and related species] is assembled at the International Crops Research Institute for the Semi-Arid Tropics near Hyderabad, India, from several collections existing earlier in India, and subsequently through collection and correspondence (ICRISAT Annual Reports 1973-1982)

2. TAXONOMY

2.1 Cultivated Pigeonpea

The pigeonpea belongs to the family Leguminosae, subfamily Papilionoideae, tribe Phaseoleae and subtribe cajaninae, of which it is the only cultivated species (Lackey, 1981; van der Maesen n.d.). Growth habit and flowering are strongly influenced by daylength and temperature. Therefore, any classification below species level tends to be of limited regional value. The Linnaean name for pigeonpea was *Cytisus cajan* L., but it clearly did not belong in *Cytisus* (Thothathri and Jain, 1981). Following Linnaeus, the Malay name Katjang or Kachang (general name for bean or groundnut) has remained with pigeonpea. Adanson used Kachang for a generic name *(Cajan* Adans.), and A. de Candolle applied it in the proper latinized form : *Cajanus* DC., now a conserved name.

Fig. 1 : A good crop of pigeonpea

De Candolle described two species in Cajanus : *C. flavus* DC. which was the Central Indian "tur", with medium plant height, yellow flower colour, 2–3 seeded pods, and stipellae half as long as petiolules, and *C. bicolor* DC. the North Indian 'arhar', with tall plant habit, flower red and yellow, 4–5 seeded pods, and stipellae about as long as petiolules. These two species were soon considered conspecific and even classification as varieties can now be ruled out, as flower colour and number of seeds per pod are based on a limited number of genes (Pathak, 1970), while in collections all possible intermediates are seen. ICRISAT breeders distingnish 10 maturity classes, which may vary by region. This is a practical approach as in soybean classification (Polhill and van der Maesen, 1985).

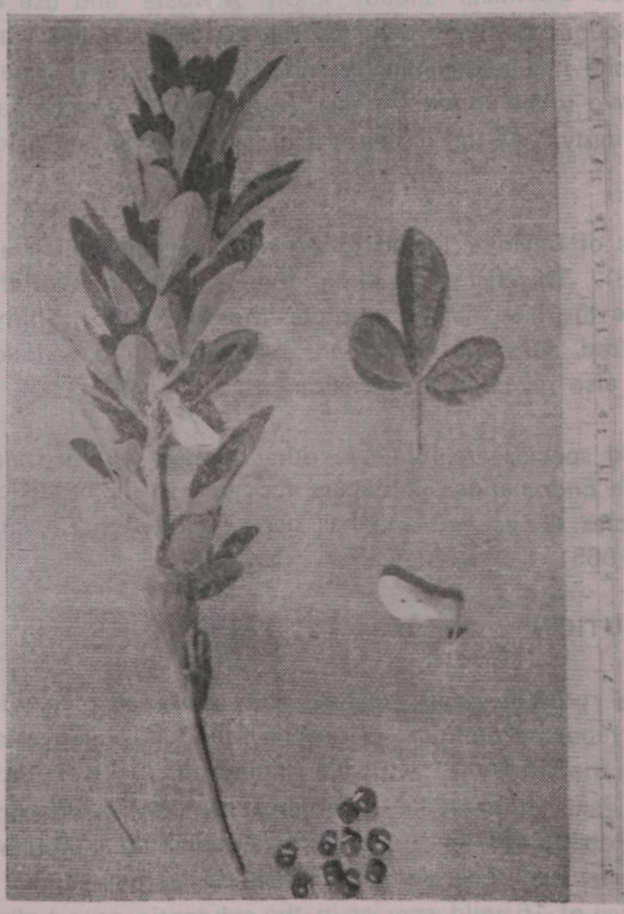

Fig. 2: *Cajanus lineatus*: a species from the western ghats of India

2.2 Related wild Species

The successful intergeneric crosses between *Cajanus cajan* and *Atylosia sericea* W. & A., *A. scarabaeoides* (L.) Benth. and *A. lineata* W. & A. confirmed the long acknowledged close relation of *Atylosia* W. & A. with *Cajanus* DC. (Kumar *et al.* 1958; Roy and De 1965, Reddy 1981 a, b, c, van der Maesen, 1985). Applied scientists often pointed to the congenericity of these genera. McComb (1975) clearly ascribed the reported successful intergeneric hybrids to misplaced generic boundaries, as are probably most reported cases of intergeneric crosses in the leguminosae.

Morphological, cytological, and biochemical similarities, the many successful and fertile hybrids, which could not be obtained with other genera in Cajaninae, make a continuation of two separate ganera unwarranted (van der Maesen, 1981). Since appiled scientists already know *Atylosia* and use its species for crossing with pigeonpea, name changes may be incovenient (Stirton, in Laceky, 1981). Despite this inconvenience and the need for many new combinations, the genera have to be united. *Atylosia* species will become part of Cajanus, as latter has priority. At this point tradition has to be set aside (van der Maesen, 1985).

Table 1 lists the species of Cajanus (including *Atylosia*) species which are recognized at present (1983). This list is waiting formal publication of the new combinations to validate the new names (van der Maesen, 1985). Thirty-two species will be recognized, some of which are subdivided in to varieties A sectional classification is also given in the revision,

Less closely related wild species are found in other Genera of the Cajaninae (Table 2) The genus *Endomallus* Gagnepain appeared to be based on specimens of a *Cajanus* species, *C. goensis* and has been included in *Cajanus* as well (van der Maesen, 1985).

3. ORIGIN AND DISTRIBUTION

Cultivated pigeonpea is grown pantropically. The presence of a wild species in west Africa, the repeated mention of seeds found in an Egyptian tomb at Dra Abu Nega from the XII Dynasty (just a single seed: Schweinfurth, 1884) and frequent finds of (sub)spontaneous pigeonpeas in Africa made many authors (e. g. Rachie and Roberts, 1974; Brucher, 1977) adhere to a probable African origin. Although diversity in East Africa is great, diversity in India is much larger, and the presence of 16 wild species in the subcontinent including the vary similar *Cajanus cajanifolius* ined., (Fig. 3) make an indian origin much more likely (van der Maesen, 1980) as was rightly favoured by De (1974) and Vernon Royes (1976). The absence of reports on pigeonpea occuring wild in India made A. de Candolle (1883) and several others favour an African origin, but this absence may be explained by a much more intensive use of tne land for agriculture and grazing. ICRISAT botanists have not found sub-spontaneous or even clearly escaped pigeonpeas but once or twic in India.

Fig. 3: *Cajanus cajanifolius*, the closest relative of pigeonpea, from E. A. P., Bastar and Orissa, India.

The pigeonpea must have reached Africa from India in a very early peiord probably, before 2000 BC (van der Maesen, 1980), and reached the Americas in the 16th century, the Pacific around 1750 AD, and Guam in 1772. With the recognition of the need for improved protein nutrition, the exchange of germplasm over the world has grown considerably since about 1960.

Table 1

Species recognized in the genus *Cajanus*, their basionyms or most widely known synonyms and their distributions.

	Species.	Basionym or most common synonym	Distribution
1.	*Cajanus acutifolius* (F. von Muell.) van der Maesen	*Rhynchosia acutifolia* F. V. Muell. ex Benth.	Australia.
2.	*Cajanus albicans* (W. & A.) van der Maesen	*Atylosia albicans* (W. & A.) Benth.	S. India. Sri Lanka
3.	*Cajanus aromaticus* van der Maesen	—	Australia
4.	*Cajanus cajan* (L.) Millsp.	*Cajanus indicus* Spreng.	Pantropic
5.	*Cajanus cajanifolius* (Haines) van der Maesen	*Atylosia cajanifolia* Haines	SE India
6.	*Cajanus cinereus* (F. van Muell) F. von Muell	*Atylosia cinerea* F. V. Muell. ex. Benth.	Australia
7	*Cajanus confertiflorus* F. von Muell	*Atylosia pluriflora* F. V. Muell. ex. Benth.	Australia
8.	*Cajanus crassicaulis* van der Maesen	—	Australia
9.	*Cajanus crassus* (Prain ex King) van der Maesen		
	var *burmanicus* (Collett & Hemsley) van der Maesen	*Atylosia burmanica* Collett & Hemsley	Burma
	var *crassus*	*Atylosia crassa* Pravin ex King	India, SE Asia
10.	*Cajanus elongatus* (Benth.) van der Maesen	*Atylosia elongata* Benth.	NE India, Vietnam
11.	*Cajanus goensis* Dalz.	*Atylosia barbata* (Benth.) Bak.	India, SE Asia
12.	*Cajanus grandiflorus* (Benth. ex. Bak.) van der Maesen	*Atylosia grandiflora* Benth. ex. Bak.	NE India, S China
13.	*Cajanus heynei* (W. & A) van der Maesen	*Dunbaria heynei* W. & A)	SW India, Sri Lanka.

Table 1 (Contd).

	Species.	Basionym or most common synonym	Distribution
14.	*Cajanus kerstingii* Harms	—	W Africa
15.	*Cajanus lanceolatus* (W. V. Fitzg.) van der Maesen	*Atylosia lanceolata* W. V. Fitzg.	Australia
16.	*Cajanus lanuginosus* van der Maesen	—	Australia
17.	*Cajanus latisepalus* (Reynolds & Pedley) van der Maesen	*Atylosia latisepala* Reynolds & Pedley)	Australia
18.	*Cajanus lineatus* (W. & A.) van der Maesen	*Atylosia lineata* W. & A.	S India, Sri Lanka
19.	*Cajanus mareebensis* (Reynolds & Pedley) van der Maesen	*Atylosia mareebensis* Reynolds & Pedley	Australia
20.	*Cajanus marmoratus* (R. Br. ex Benth) F. von Muell.	*Atylosia marmorata* R. Br. ex Benth.	Australia
21.	*Cajanus mollis* (Benth.) van der Maesen	*Atylosia mollis* Benth.	Himalaya foothills
22.	*Cajanus niveus* (Benth.) van der Maesen	*Atylosia nivea* Benth.	Burma, S China
23.	*Cajanus platycarpus* (Benth.) van der Maesen	*Atylosia platycaroa* Benth.	Indian subcontinent, Java
24.	*Cajanus pubescens* (Ewart & Morrison) van der Maesen	*Atylosia pubescens* (Ewart & Morrison) Reynolds & Pedley	Australia
	var. *mollis* Reynolds & Pedley	var. *mollis* Reynolds & Pedley	
	var. *pubescens*	—	

Table 1 (Contd.)

	Species.	Basionym or most common synonym	Distribution
25.	*Cajanus reticulatus* (Dryander) F. von. Muell.		
	var. *grandifolius* (F. von. Muell.) van der Maesen.	*Atylosia grandifolia* (F. v. Muell.) Benth.	Australia, N Guinea
	var. *reticulatus*	*Atylosia reticulata* (Dryander) Benth.	Australia.
	var. *maritimus* (Reynolds & Pedley) van der Maesen.	—	Australia.
26.	*Cajanus rugosus* (W. & A) van der Maesen	*Atylosia rugosa* W. & A.	S India, Sri Lanka
27.	*Cajanus scarabaeoides* (L.) Thouars	*Atylosia scarabaeoides* (L.) Benth.	
	var. *pedunculatus* (Reynolds & Pedley) van der Maesen	var. *pedunculatus* Reynolds & Pedley	Australia
	var. *scarabaeoides*	*Atylosia scarabaeoides* (L.) Benth	S, SE Asia, Pacific, Coastal Africa
28.	*Cajanus sericeus* (Benth. ex. Bak.) van der Maesen	*Atylosia sericea* Benth. ex Bak.	S India
29.	*Cajanus trinervius* (DC.) van der Maesen	*Atylosia candollei* W. & A.	S India, Sri Lanka
30.	*Cajanus villosus* (Benth. ex Bak.) van der Maesen	*Atylosia villosa* Benth. ex Bak.	NE India
31.	*Cajanus viscidus* van der Maesen	—	Australia
32.	*Cajanus volubilies* (Blanco) Blanco	—	Philippines, Indonesia.

Table 2

Genera in the Subtribe cajaninae

Group Cajanastrae (Baudet 1978)	Group Rhynchosiastrae (Benth.) Baudet
Multi-ovuled ovary Distr. mainly Asian	2-ovuled ovary Distr. mainly African
Baukea Vatke (1 sp.)	*Adenodolichos* Harms (15 spp.)
Bolusafra Kuntze (1 sp.)	*Carissoa* Bak. f. 1 sp.)
Cajanus DC. (32 spp.)	*Chrysoscias* E. Mey (15 spp.)
Dunbaria W. and A. (15 spp.)	*Eriosema* (DC.) G. Don (130 spp.)
	Flemingia Ait. f. (30 spp.)
	Paracalyx Ali (6 spp.)
	Rhynchosia Lour. (200 spp.)

Fig. 4: *Cajanus goensis*: a twining relative of pigeonpea

Sixteen of the wild species of *Cajanus* are distributed in the Indian sub-continent. There are 12 endemic wild species in Australia, one of which extends to SE New Guinea, and this area has one widespread species in common with India, the Pacific and coastal Africa. *C. scarabaeoides* (L.) du Petit-Thouars. In West Africa a single endemic species is found: *C. kerstingii* Harms. It is not as close to pigeonpea morphologically as the Indian *A. cajanifolia.* Apart from the common variety, there is an endemic variety of *C. scarabaeoides* in Australia.

Fig. 5 : *Dunberia* : a vigorous climber of a genus related to *Cajanus*

4 GERMPLASM COLLECTIONS

4.1. Explorations

Explorations for pigeonpea germplasm have most often been combined with those undertaken for other crops, in particular pulses. From 1966-70 the Regional Pulse Improvement Project (RPIP) (USAID/IARI) made field collections mainly in Northern India. From 1974 onwards ICRISAT carried out pointed collections for cultivated and wild pigeonpea in India, Eastern and Southern Africa, Thailand, the Philippines and Nepal (Progress Reports, Genetic Resources Unit, mimeographed). For the areas visited the diversity present can be considered to be well covered. From the many tropical countries where pigeonpea was introduced long ago or more recently, local adaptation can be expected. In total the world collection is still far from complete. A good collection of wild species is now available (Remanandan, 1981), although not all known species are included in this collection. Pulse scientists in India often enriched the germplasm by regional explorations (Sindhu, Kanpur, Venkateswarlu, Varanasi; personal communication) and the collectors of the National Bureau of Plant Genetic Resources (New Delhi) collect pigeonpea in the course of their general collection efforts. The International Institute for Tropical Agriculture (Ibadan, Nigeria) collected about 300 accessions from African countries, where pigeonpea cultivation is generally thinly spread and therefore where pointed collections for pigeonpea alone would not pay. Some collections once available in the West Indies were lost due to discontinuity in funding. However, several entries of those collections are available in the world collection of ICRISAT although a better renewed representation is needed.

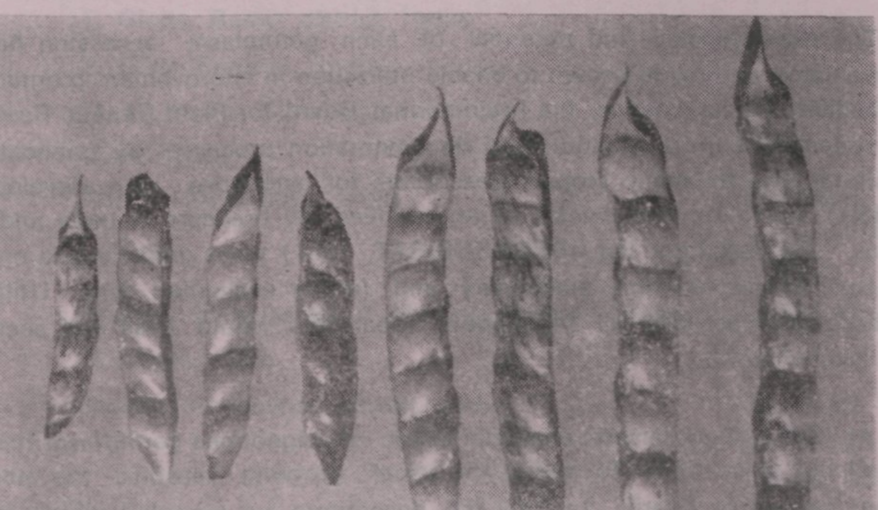

Fig. 6 : Diversity in seed number per pod

National Seed Storage Laboratory, Fort Collins, Colorado, USA, has played an important role in storing between 1970 and 1977 the world collection originally assembled in India. Table 3 lists the collection efforts primarily undertaken to assemble pigeonpea germplasm.

4.2. Collection in Gene Banks

The world collection of pigeonpea germplasm, assembled at ICRISAT, counts about 10,000 accessions in mid 1983. Much of the collection was donated by the Regional Research Station of the Indian Agricultural Research Institute (IARI) at Rajendranagar near Hyderabad, which had held duplicates of the collection gathered by RPIP (RPIP, 1967, 1968). Important donations came from the Agricultural Universities in India. Gaps in the existing collection were filled by importation from Mayaguez, Puerto Rico, where the seeds from the original Indian collection stored at Fort Collins were sent for first rejuvenation. Table 4 lists the gene banks where pigeonpea collections are held. In addition, several breeders maintain their own working collection. Table 5 lists the origin of entries in the world collection at ICRISAT.

5. EVALUATION OF PIGEONPEA GERMPLASM

The characteristics and potential of each germplasm accession have to be evaluated and made known to enable utilization in improvement programmes. To facilitate data exchange, the International Board for Plant Genetic Resources has streamlined the evaluation and documentation processes by publication of descriptor lists for many crops. Descriptors for pigeonpea were developed at ICRISAT based on many years of experiences by breeders in India and elsewhere. The descriptor list (IBPGR/ICRISAT, 1981) gives guidelines to organize passport, characterization, preliminary and further evaluation data. Utilization of these descriprors by all pigeonpea researchers would ease and accelerate data exchange.

At ICRISAT systematic characterization of pigeonpea germplasm has been carried out since 1974-75 during the usual growing seasons, the monsoon (rainy) season or Kharif. In total 52 descriptors are recorded which include passport data, morphological and agronomic traits, protein content and reaction to diseases and pests. The accessions are sown in precision fields without replication, but with frequent checks.

Table 3

Explorations with pigeonpea and/or wild relatives as main goal or important component

Year	Area	Agency
1965	North and North Central India	RPIP (till 1970)
1974	Madhya Pradesh, India	ICRISAT
1975	,,	,,
1975	W. Ghats, Maharashtra, India	,,
1975	W. Bengal, Bihar, India	,,
1976	Southern hills, Tamil Nadu, India	,,
1976	N. Karnataka, India	,,
1976	Tirumalai hills, Andhra Pradesh, India	,,
1976	Orissa, Bihar, India	,,
1976	Kenya	ICRISAT, Univ. of Nairobi
1976	Nilgiri hills, Tamil Nadu, India	ICRISAT
1977	Tamil Nadu, India	,,
1977	E. Ghats, Bastar district, India	,,
1977	E. Uttar Pradesh, India	,,
1977	N. W. India, Himalayan foothills	,,
1977	South India	,,
1978	Assam, Meghalaya, India	ICRISAT; ICAR, Univ. of Agric. Jorhat
1978	Gujarat, Maharashtra & Madhya Pradesh, India	ICRISAT
1979	W Ghgts, India	,,
1979	Assam, Meghalaya. Sikkim, India	ICRISAT, ICAR, Univ. of Agric. Jorhat, Dept. Agric. Sikkim
1979	Australia	ICRISAT, Dept. of Primary Industries, Australia

Table 3 (Contd.)

Year	Area	Agency
1979	S. Indian hills	ICRISAT
1979	E. Nepal	ICRISAT, Dept. of Agric., Nepal
1979	Bangladesh	ICRISAT
1979	Bundelkhand, Madhya Pradesh	"
1980	W and E Ghats, India	"
1980	Sri Lanka	"
1980	N. W. Thailand	ICRISAT, Chiangmai Univ.
1980	Burma	ICRISAT
1980	W. Nepal Punjab	ICRISAT, Dept. of Agric., Nepal
1980	Garhwal, Kumaon, India	ICRISAT
1981	Luzon, the Philippines	ICRISAT, IRRI
1981	E. Ghats	ICRISAT
1981	Tanzania	ICRISAT, IITA/ USAID/Tanzania Project, Min. of Agric. Tanzania
1981	Silent Valley, Attapadi Hills	ICRISAT
1982	Kenya	ICRISAT, FAO, Min. of Agric, Kenya
1982	N. W. Bengal, Sikkim, India	ICRISAT
1982	N. E. Uttar Pradesh, Himalayan foothills	ICRISAT
1983	Orissa, India	ICRISAT
1983	Malawi	ICRISAT, Min. of Agric. Malawi

Note : Numerous trips by IITA, Nigeria, NBPGR, India and those sponsored by IBPGR, have yielded pigeonpea accessions, not all of which are duplicated yet in the World Collection.
Explorations for other ICRISAT crops also yielded pigeonpeas.

Table 4

Gene Banks maintaining collections of Pigeonpea Germplasm

Country	Institute	Acc.	Cold Storage
India	ICRISAT, Patancheru	10,000	Medium term
Bangladesh	BARI, Joydebpur, Dhaka	+ 100	—
Colombia	CIAT, Cali.,	30+	Long+short term
Malawi	Chitedze Agr. Res. Station, Lilongwe	30+	—
Nigeria	IITA, Ibadan	?	Long+medium term
Philippines	Univ. at los Banos	300	Long+medium term
Romania	Inst. Cerc. Cereale Pl. Technice, Fundulea	?	—

Source : IBPGR Directory of Germplasm collections, Food Legumes 1980, and Plucknett *et al.*, 1983.

Table 5 a

World Germplasm Collection of Pigeonpea at ICRISAT (1-2-1984)

Country	No. of accessions
Australia	47
Bangladesh	57
Brazil	7
Burma	63
Colambia	5
Dominican Republic	6
French Antilles	4
Ghana	2
Guyana	7
India	8744
Indonesia	4
Jamaica	18
Kenya	64
Madagascar	1
Malawi	20
Mexico	2
Nepal	116
Nigeria	27
Pakistan	14
Peru	5
Puerto Rico	45
Philippines	37
Senegal	10
South Africa	1
Sri Lanka	70
Taiwan	3
Tanzania	167
Thailand	20
Trinidad	22
USSR	2
USA	3
Venezuela	15
Zambia	20
Unknown (source New Zealand)	1
Total	9648

Table 5 b

Statewise distribution of Pigeonpea Germplasm from India (1-2-1984)

State	No. of accessions
Andhra Pradesh	2215
Assam	106
Bihar	641
Daman	1
Gujarat	125
Haryana	3
Himachal Pradesh	4
Karnataka	265
Kerala	31
Madhya Pradesh	731
Meghalaya	2
Maharashtra	524
New Delhi	111
Orissa	213
Punjab	31
Rajasthan	39
Sikkim	4
Tamil Nadu	346
Uttar Pradesh	1991
West Bengal	130
ICRISAT developed lines	671
Unknown	560
Total	8744

Multilocation evaluation is necessary as each genotype or maturity group has a specific area of adaptaion (Sharma *etal.,* 1981). Even within a maturity group the individual lines react differently when exposed to other seasons or locations. Flowering and fruiting are markedly influenced by altitude and latitude, and pigeonpea is a quantitative short day plant. Landraces perform well in or near their areas of origin, and tneir performance elsewhere cannot be easily predicted.

6. MAINTENANCE AND CONSERVATION

6.1. Field Practice

Pigeonpea is a partially outcrossing species, which complicates the maintenance of the entries as inbred samples. Natural outcrossing varies from 3-40% (Khan and Rachie, 1972). Traditional landraces grown by farmers are not always homogeneous. Maintenance should be carried out in such a way as to conserve the diversity as much as possible as in the original population in the farmer's field. Pigeonpea does not suffer from inbreeding depression, but genetic drift is most likely to limit the diversity in homozygous inbred samples.

At ICRISAT the strategy is to secure the required seed in the first generation itself, and limit further cycles of increase. Genetic purity of the original population is maintained by selfing ca 30 plants per accession and bulking the self seed. The self seed is used for rejuvenation and seed supply is from open pollinated seed. At present selfing is carried out by covering whole plants or branches with muslin bags (Fig. 7). More economic and efficient methods are under evaluation.

The required isolation between genotypes as reported varies between 9 m (Trinidad) and 200 m (ICRISAT's practice, see also Bhatia *et al.,* 1981). Bhatia *et al.,* (1983) found 1.7-4.8% outcrossing between plots spced at 100 m. This distance is considered adequate to avoid pollination and outcrossing then expected not to surpass (an average) 3%. Large flowers often have a 'wrapped' condition, where the petals separate and open late, ensuring more selfpollination. Marker genes such as purple stems or obcordate or obtuse leaflets permit a check on outcrossing.

Interpollination is promoted in germplasm collections where many different genotypes are grown side by side. Self-pollination takes place before the flowers open, but pollen from other plants is often favoured. Certation as such has not been established with certainty.

Routine germination tests of the stored seed are carried out in order to ensnre the viability of the stored seed and monitor any decline in viability. Done every five years, with 4 replications of 50 seeds each, depletion of seed is faster than is needed for the sequential testing as proposed by Ellis, Roberts and Whitehead (1980 see also van der Maesen, 1984).

The quantity of seeds which should be stored is based on estimates of expected seed supply and storage facilities. For heterogenous material IBPGR recommends 12,000 seeds per sample (Cromarty, Ellis and Roberts, 1982). At ICRISAT about 1 kg. of seeds is stored.

Fig. 7 : Large scale selfing of pigeonpea with muslim bags

6.2. Storage

For planning efficient and economic seed stores Cromarty *et al.*, (1982) is the most recent comprehensive reference. Pigeonpea seed may be stored in any con venient container. However, it should be moisture-proof if the humidity in the store is not controlled, Airtight containers are available in plastic, tin, aluminium, glass (with rubber-lined caps) or as foil pouch. The stores, preferably with movable racks and shelves to save space, should be cooled down to a temparature suitable for maintenance of viability for the period required (Fig. 8). For medium-term storage IBPGR standards are about +5 C and 30 to 40% RH. For long-term storage the temperature should be —18 to —20 C (Cromarty *et al.*, 1982). Under these conditions seeds should remain viable at least 25 and 100 years respectively. Rao *et al.*, (1982) found that even storage in airconditioned dehumidified rooms (16 to 20 C; 50 to 60% RH), viability of pigeonpea seeds retained about 92% germination after 4 years except for one cultivar which had 81% germination. In contrast, viability was much lower when the seed was stored under ambient conditions.

Fig. 8 : A cold store for germplasm

Seeds should be dried to the required moisture level before moving them into the store. For storage at -20 C the moisture level has to be reduced to 4.5% and for storage at + 5 C it should be not more than 8%. Seeds of 12% moisture deteriorate very quickly. If harvested during the dry season in India, sun drying is quite satisfactory for medium term storage.

In storage under ambient conditions insects are a great threat unless seeds are kept scrupulously clean and no bruchid eggs are present. A naphtalene ball in each seed bottle prevents any insect outbreak and has no influence on the germination of the seed and subsequent seeding gtowth.

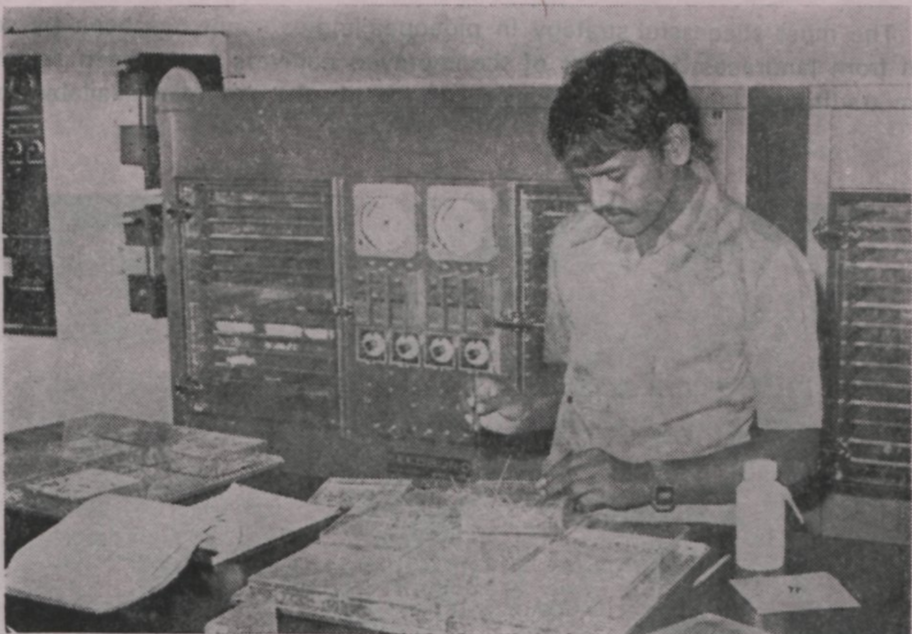

Fig. 9 : Germination test to monitor viability

7. UTILIZATION

Well-preserved genetic resources are an insurance against loss of diversity and provide the material needed for further improvement. Important are availability of seed and access to information, Characterization data of more than 9000 accessions orlginating from 33 countries are now available at ICRISAT. Table 6 presents the range of variability present in the collection.

The world collection also contains lines resistant to wilt, sterility mosaic disease, and blight, lines tolerant to insects, and photoperiod-insensitive genotypes, etc (Table 7). The data retrieval system IDMRS provides information about character combinations to suit the needs of the users.

To broaden further the genetic base of pigeonpea, interspecific hybrids many of which are fertile, can be used. Remanandan (1981) reviewed the genetic resources of wild taxa available at ICRISAT, the introgressed progenies and their possible areas of utillzation. Desirable traits available in readily crossable species Include male sterility, photoperiodic insensitivity, stem blight resistance, high protein content, resistance or antibiosis to pod borer, pod fly and bruchids.

The most successful strategy in pigeopea improvement has been by selection from landraces, and most of the improved cultivars have been selections from traditional landraces. However, much of the potential available in the

Fig. 10 : An example of interspecific cross
Cajanus lineatus x *albicans*, with the parents
Left : *Cajanus lineatus*
Right : *Cajanus albicans*
Middle : *Cajanus lineatus* x *Cajanus albicans*

germplasm is yet to be exploited. In the coming years breeders are likely to depend more on the diversity in germplasm and we believe that a quantum jump in pigeonpea yield is a definite possibility. "Access to genetic variability is, in most characters, excellent or at least adequate". For the quantitative, phenological, and agronomic characters of interest, there appears to be a huge range of variation available, and the simple fact is that we have hardly commenced to tap it" (Byth, 1981).

Table 6

Range of Variation observed in Pigeonpea Germplasm at ICRISAT

Character	Range
50% flowering (days)	55 – 228
75% maturity (days)	105 – 260
Plant height (cm)	39 – 400
Primary branches (No.)	2 – 66
Secondary branches (No.)	0.33 – 145
Racemes (No.)	10 – 788.7
Seeds per pod	2 – 8.5
100 seed weight (g)	2.8 – 22.4
Harvest index (%)	2.3 – 52.2
Shelling ratio (%)	7.5 – 88.1
Protein percentage	13.9 – 28.6
Yield per plant (g)	upto 357.3

Wild species have upto ca 34% protein

Table 7

Some Pigeonpea Accessions with Useful Characteristics

1. Fusarium wilt resistant lines (ICP Nos.)

   8858 8859, 8860, 8861, 8862, 8863, 10958, 10960, 11292, 11294, 11299, 11720, 12732, 12733, 12737

2. Sterility mosaic disease resistant lines (ICP Nos.)

   6986, 7201, 7349, 9150, 10976, 10977, 10980, 11032, 11034, 11035, 11068, 11109, 11120, 11196, 11297

3. Phytophthora blight resistant lines (ICP Nos.)

   28, 339, 1120, 1151, 2376, 4762, 6974, 7065, 7182 7269, 7624, 8289, 8332, 11301, 11304

4. Pod borer and podfly tolerant lines (ICP Nos.)

   11953, 11958, 11959, 11961, 11962, 11964, 11965, 11966, 11967, 11968

5. Vegetable types (Large seeded)

   ICP 3782, ICP 3783, ICP 6926, ICP 6997, ICP 7035, ICP 7119 (HY 3C), ICP 7977, ICP 7979, ICP 8501, ICP 8504, ICP 12049, ICP 12062 PRN 246, PRN 260, PR 6011

6. High yielding lines

   ICP 11537 (ICPL 81), ICP 11543 (ICPL 87), ICP 11717 (ICPL 267), ICP 7178, ICP 7220 (Prabhat), QPL 67, ICP 6971 (UPAS 120), ICP 7018, ICP 7025, ICP 6, ICP 7182 (BDN 1), ICP 11720 (ICPL 270), ICPH 6, ICP 8858, ICP 6982, ICP 11746 (ICPL 296), ICP 528, ICP 1214, ICP 8142, ICP 7915 PR 6006, PR 6018, PR 6076, PR 6135 1, ICP 12073, ICP 12100, ICP 12113, PR 5570, PRN 99, PRN 122 PRN 233.

Not a complete list.

8. SUMMARY AND CONCLUSIONS

The pigenpea belongs to family leguminosae, subfamily Papionoideae, tribe phaseoleae and subtribe Cajanae of which it is the only cultivatedspecies. Because of the morphological, cytological and biochemical, similarities between *Cajanus cajan* and different species of *Atylosia* as well as successful intergeneric crosses between *Cajanus* and *Atylosia* spp., these two genera have been united and 32 species of *Cajanus* (including *Atylosia*) are enlisted. Details of explorations by different agencies for the collection of pigeonpea germplasm are presented. Techniques of maintaining and conserving pigeonpea germplasm are described. Possible utilization of available germplasm in breeding programmes is expected to result in quantum jump in pigeonpea yields.

REFERENCES

Bhatia, G. K., Sharma, D., and Faris, D. G., 1983. *Int. Pigeonpea Newslett.* 2 : 27–28.

Bhatia, G. K. Gupta, S. C., Green, J. M., and Sharma, D. 1981. *Proc. Int. Workshop Pigeonpeas,* 15-19 December 1980, 2, pp. 129-136. ICRISAT.

Brucher, H. "Tropische Nutzpflanzen." Sprenger Verl. Berlin–Heidelberg–New York, 166-167.

Byth, D. 1981, *Proc. Int. Workshop Pigeonpeas,* 15–19 December 1980, 1, pp. 487–495. ICRISAT.

Candolle, A. de. 1883. "Origine des Plantes cultivates". pp. 266–268.

Cromarty, A. S., Eliis R. H., and Roberts, E. H. 1982. "The design of seed storage facilities for genetic conservation." International Board for Plant Genetic Resources (IBPGR), Rome. pp. 96.

De, D. N. 1974. *In* "Evolutionary Studies in World Crops" (Sir J. Hutchinson, ed.) pp. 79–87.

Ellis, R. H., Roberts, E. H., and Whitehead, J. 1980. *Pl. Genet. Resources Newslett.* 41, 3–28.

Frankel, O. and Bennett, E. (eds.) 1970. Genetic Resources in Plants-their Exploration and Conservation.' IBP Handbook 11, Blackwell.

Frankel, O. H., and Hawkes, J. G. (eds.) 1975. "Crop Genetic Resources for Today and Tomorrow." Cambridge Univ. Press.

Harlan, J. R. 1975. *Science* 188 : 618-621.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1975-82. Annual Reports. Hyderabad/Patancheru, India.

IBPGR/ICRISAT (International Board for Plant Genetic Resources/International Crops Rasearch Institute for the Semi-Arid Tropics). 1981. "Descriptors for Pigeonpea." pp. 15.

Khan, T. V., and Rachie, K. O. 1972. *E. Afr. Agric. For. J.* 38, 78-82.

Kumar, L. S. S., Thombre, M. V., and D'Cruz, R. 1958. *Proc. Indian Academy of Sciences*. Sec. B 47 : 252-262.

Lackey, J. 1981. "Advances in Legume Systematics". (R. M. Polhill, and P. H. Raven, eds.). Part I, pp. 301-327.

McComb J. A. 1975. *Euphytica* 24 : 497-502.

Pathak, G. N. 1970. *In* "Pulse Crops of India", pp. 14-53. ICAR, New Delhi, India.

Polhil, R. M., and van der Maesen, L. J. G. 1985. Taxonomy of Grain Legumes. *In* "Grain Legume Crops" (R. J. Summerfield, ed.) Granada Publ. Ltd.

Plucknett, D. L. Smith, N. J. H., Williams, J. T., and Murthi Anishetty, N. 1983. *Science* 220, 163-169.

Rachie, K. O., and Roberts, L. M. 1974. *Adv. Agron*. 26 : 1-132.

Rao, N. K., van der Maesen, L. J. G., and Remanandan, P. 1982. *Neth. J. Agric. Sci.* 30, 99-103.

Reddy, L. J., 1981 a. *Cytologia* 46 : 397-412.

Reddy, L. J. 1981 b. *Cytologia* 46 : 576-577.

Reddy, L. J. 1981 a. *Cytologia* 46 : 579-589.

RPIP (Regional Pulse Improvement Project). 1967. "Annual Progress Report" 5 : 139-140.

RPIP (Regional Pulse Improvement Project), 1968. "Annual Progress Report" 6 : 113-114.

Remanandan, P. 1281. *Proc. Int. Workshop Pigeonpeas.* 15–19 December 1980, 2, pp. 29–38. ICRISAT.

Roy, A. and De, D. N. 1965. *Science and Culture* 31 : 93–95.

Sharma, D., Reddy, L. J., Green, J. M., and Jain, K. C. 1981. *Proc. Int. Workshop Pigeonbeas.* 15–19 December 1980. 1, pp. 71–81. ICRISAT.

Thothathri, K., and S. K. Jain. 1981. *Proc. Int. Workshop Pigeonpeas* 15–19 December 1980, 2, pp. 3–7. ICRISAT.

van der Maesen, L. J. G. 1981. *Proc. Int. Workshop Pigeonpeas* 15-19 December 1980, 2, pp. 9-13. ICRISAT.

van der Maesen, L. J. G. 1983. *Miscellaneous Papers of the Agricultural University, Wageningen* 19 : 257-262.

van der Maesen, L. J. G. 1984. In "Genetic Resources and their Exploitation–Chickpeas, Febabeans and Lentils" (J. R. Witcombe, and Erskine, eds.). Martinus Nijhoff, The Haque.

van der Maesen, L. J. G. 1985. "A revision of all taxa closely related to the pigeonpea, with notes on other related genera within the subscribe Cajaineas. *Agricultural University, Wageningen Papers* 85–4.

van der Maesen, L. J. G., Remanandan, P., and Anishetty Murthi, N. 1981. *Proc. Int. Workshop Pigeonpeas* 15–19 December 1980, 1, pp. 385–392. ICRISAT.

Vernon Royes, W. 1976. *In* ' evolution of Crop Plants" (N. W. Simmonds ed.). pp. 154-156. Longman, London and New York.