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CHARACTERISTICS AND POTENTIAL USES OF SOME GENETIC STOCKS OF PEARL MILLET IN THE WORLD COLLECTION

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The world germplasm collection of pearl millet [Pennisetum glaucum (L) R. Br.] consisting of 21,772 accessions from 44 countries is being maintained at ICRISAT Centre, Patancheru, India. Most of the material has been evaluated and characterised to identify traits of economic importance for present and future utilisation. Promising accessions identified as sources of disease resistance are 1220 to downy mildew, 151 to ergot, 161 to smut and 392 to rust. Other genetic stocks and seedling markers identified are 145 dwarfs, 3 midribless, 8 glossy and many viable chlorophyll deficient mutants. New male sterile lines identified from Ghana and Botswana germplasm are early-maturing and produce large grains. Sweet stalk types with high sugar content are useful to develop fodder types. Early-flowering stocks are useful to develop early-maturing high-yielding cultivars. Germplasm from West Africa is a good source for disease resistance, high head volume and large grain size.

Pearl millet [*Pennisetum glaucum* (L) R. Br.] had originated in a diffuse belt from Sudan to Senegal most probably around Mali-Mauritania (Brunken *et al.*, 1977) and spread to other countries where considerable diversity had accumulated. The world collection of pearl millet comprising of 21,772 accessions from 44 countries is being maintained at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. As and when the germplasm material is collected or acquired, they are evaluated as per the standard pearl millet descriptors (IBPGR/ICRISAT, 1981) and traits of economic importance are identified. Enormous variation was observed for several morpho-agronomic characters (Murty *et al.*, 1967; Mengesha, 1984; Mengesha and Appa Rao, 1986; Harinarayana *et al.*, 1988). Accessions possessing these economic traits are maintained as genetic stocks collection and the results of evaluation and screening data are summarised in this paper.

GENETIC STOCKS OF ECONOMIC IMPORTANCE

Source of economically useful traits are identified through systematic screening of world germplasm (Table 1) with a view to incorporate them in the improved cultivars.

Early flowering and maturity

Days to flowering and maturity assume special significance as pearl millet is grown under relatively dry conditions. In the world collection, flowering ranged from 33 to 140 days offering wide scope for tailoring the genotypes to suit different

Table 1. Sources of resistance identified in pearl millet germplasm

Screened for	Number of accessions	
	Screened	Resistant
1. Disease Resistance		
Downy mildew	3163	1220
Ergot	2554	151
Smut	941	161
Rust	2670	392
2. Insect Resistance		
<i>Mythimna</i> spp.	100	0
Shoot fly	424	45
Aphids	100	14
Shoot bugs	100	8
Thrips	29	3
Spider mites	234	31
3. Other characters		
Drought Resistance	509	2
Early	16968	8
High protein	3523	100
High sugars	3008	4
Male sterility	16968	7
Glossy leaf	16968	8
Dwarf lines	15388	145
Midribless	17000	3
Chlorophyll mutants	16968	150

environmental conditions and farming systems. Early flowering appears to be controlled by two genes e_1 and e_2 (Hanna and Burton, 1985) and plants having e_1e_1 flowered in 49 days and e_2e_2 genotype in 38 days as compared to the control (76 days) when grown at Tifton, Georgia. After screening the world collection of 18,148 accessions, 7 genotypes that flowered earlier than Tift 23BE having e_1e_1 gene were identified. Among them, IP 4021 (*Bhilodi*) collected from Gujarat which flowered in 33 days was the earliest. A comparison of the phenology of parents and F_1 s revealed that late flowering is partially dominant, dominant or overdominant. The differences in flowering time between Tift 23BE and Bhilodi were controlled by 1 or 2 genes (Appa Rao *et al.*, 1988a). ICRISAT constituted a medium maturity composite by random mating 197 geographically diverse Indian and African lines, all flowering in 45-55 days.

Dwarfs

The inheritance of five dwarfs was studied (Burton and Fortson, 1966) and two stocks were identified in which dwarfing was conditioned by a single recessive gene, d_1 or d_2 . The d_2 gene has been incorporated into male sterile (ms) lines like Tift 23A₁, Tift 239A₂, 126A₁ and 81A₁. Seven diverse tall composites have also been converted into d_2 background providing a broad dwarf genetic base for breeding dwarf parents and dwarf open pollinated varieties (Andrews *et al.*, 1985). Subsequently, over 40 dwarf stocks were identified and mode of inheritance of 13 stocks was studied. When these 13 dwarfs were crossed to Tift 23d₂B (d_2 dwarfing stock), 8 were found to be allelic and 5 were found to be non-allelic to d_2 . Of these five, one was allelic to d_1 , two showed continuous variation for plant height, and two stocks were found to be non-allelic to d_1 and d_2 . These simply inherited dwarfs, which are non-allelic to each other, were assigned new gene symbols d_3 and d_4 . These dwarfs possess several agronomically desirable characters besides reduced height (Appa Rao *et al.*, 1986). They can be used in millet improvement to produce cultivars with reduced height.

Sweet stalk types

The search for alternate uses of pearl millet revealed the occurrence of genotypes with high sugar content in their stems. Among sweet stalk pearl millet cultivars, considerable variation for juiciness and sweetness of the stalks was observed. Comparative studies at ICRISAT indicated 5 to 20 per cent sugar in 8 accessions, 4 of which are from Tamil Nadu (Appa Rao *et al.*, 1982). Sweet stalk types from Tamil Nadu flower late and grow very tall when compared to normal genotypes. They appeared to be good fodder types.

Sugar content in 68 genotypes studied at Coimbatore ranged from 3 to 16 per cent (Harinarayana *et al.*, 1988). The genotype FD 832 recorded the highest sugar content of 16.2 per cent followed by NEP 18-5023-2 (15 %) and Giant Bajra (13.8 %). Popularisation of sweet pearl millet for extraction of jaggery like in sweet sorghums may be beneficial in pearl millet growing areas of the semi-arid tropics.

Large spikes

Most of the accessions from India and southern Africa produced shorter spikes compared to those from West Africa. The accessions from Nigeria and Niger

produced the largest spikes where the Gero, Zongo and Maiwa forms produce more than 1m long spikes. Those with longer spikes produced fewer tillers, mature later, and are often strongly photoperiod sensitive. •

Seed characters

The seed size in pearl millet varied from very small (2.39 g/1000 grains as in IP 3100) to very bold (23 g/1000 grains as in IP 10437) with different grades of sizes. Bold seeded collections predominantly occurred in accessions from Benin, Ghana, Togo and Uganda. Light pigmented pearl millet grains which vary from white to yellow were identified in germplasm from Chad, Central African Republic, Ghana and Sudan (Appa Rao *et al.*, 1985). These pearly pearl millets are also sweeter and contain higher protein (more than 15 %) and may have good scope in improving nutritional quality and appearance of bakery products (Harinarayana *et al.*, 1988). These may also find a place in irrigated farming and acceptability by the elite segment of the society.

High seed protein

Seed protein content in 3523 samples was analysed and 100 accessions with the high protein content were selected. The protein content ranged from 15.5 to 20.2 per cent and the 1000 seed weight ranged from 3.2 to 12.8 g in the selected accessions. There are several lines having more than 15 per cent protein and seed weight more than 7 g, which are useful in millet improvement. Such lines are mainly from West Africa.

Cytoplasmic male-sterility

Several new male-sterile lines were identified from Ghana and Botswana germplasm (Appa Rao *et al.*, 1989). These male-sterile lines flower earlier than all the existing CMS lines and they have larger grain size. It is hoped that commercial hybrids with early maturity, large grain size, wide adaptability and higher grain yield can be produced after identifying suitable restorer lines.

USEFUL GENETIC STOCKS

Glossy types

After screening the world collection of 16,968 accessions from 31 countries, glossy trait was observed in eight accessions (Appa Rao *et al.*, 1987). The glossy characteristic was distinguishable at seedling emergence and persisted for 28 days. Mist accumulated as droplets on glossy leaves. Glossiness was due to a single recessive gene in each case and three different non-allelic genes, gl_1 , gl_2 and gl_3 , governed this trait. Glossiness appeared to be associated with seedling drought tolerance.

Midribless mutants

Three spontaneous midribless mutants identified were characterised by leaf blades that tend to droop because of the absence of a keel in the midrib portion of the leaf lamina. Androecium and gynoecium were affected in both the mutants. A single

recessive gene controlled midribless trait in each of the three mutants. Two different genes *mr1₁* and *mr1₂* were identified. These mutants are useful to study the structure and function of the midrib (Appa Rao *et al.*, 1988 b).

Chlorophyll deficient mutants

Several lethal and non-lethal chlorophyll deficient mutants have been reported in pearl millet. Naturally occurring non-lethal chlorophyll deficient mutants, not reported so far, were studied. All the leaves of the 'bright-yellow' mutant were shiny and deep yellow from emergence to maturity. The 'chlorina-virescent' mutant produced yellow leaves, which turned pale green after flowering. The 'greenish-yellow' mutant retained its pale-yellow colour from emergence to grain filling. All the mutants, could be identified in the seedling stage. In all the mutants, flowering was delayed compared to the corresponding normal genotypes. It was established that in each case the mutant condition was governed by a single recessive gene (Appa Rao *et al.*, 1984). As most of the mutants can be identified soon after germination, they can be used as seedling markers for mapping chromosomes.

Stripe mutants

Stripe plants show longitudinal yellow or white stripe, alternating with varying shades of green, on leaf blades, leaf sheaths, internodes, peduncles, inflorescences, and spikelets. Several stripe mutants were found which differ in number, size, and colour of the stripes. Segregation data indicated that the yellow spikelet colour was monogenic recessive to the green colour and stripe plants are considered to be chimeras (Appa Rao and Mengesha, 1984).

The plastids from green tissue of fully expanded stripe leaves were normal, and those from yellow tissue of fully expanded leaf were enclosed by a typical double membrane envelope. They were irregular in shape and relatively smaller than the normal plastids but equal in number. Majority of the cells in pure yellow stripes contain no normal plastids. In the overlapping regions of yellow and green stripes, however, occasional cells with normal and aberrant plastids were found (Reddy *et al.*, 1988). These mutants are of considerable academic interest.

DISEASE RESISTANCE

Downy mildew, ergot, smut, and rust are the important diseases of pearl millet. Downy mildew, in particular, devastated the single cross hybrids in India (Rai and Singh, 1987). Ergot and smut occur in favourable seasons and may be less widespread and less threatening. Rust occurs sporadically. Nevertheless, all these diseases deserve effective control to reduce losses in productivity and to eliminate the toxic principles in the food grains and in the stover. The incorporation of host plant resistance offers the best choice for effectively checking the occurrence and spread of these diseases.

Downy mildew resistance

Ex-Bornu, from Nigeria, 3/4 Ex-Bornu and 3/4 Hainei Kirei from Niger contributed to downy mildew resistance (Andrews *et al.*, 1985). Of the 3,163 accessions screened

for downy mildew resistance, 1220 were found to be resistant, of which 428 flowered in 45-60 days (Singh *et al.*, 1987). Sources of resistance were found in West Africa, mainly in Mali, Niger, Nigeria and Senegal. This is mainly because the host plant also appeared to have evolved along with the pathogens and resistance was found along the centre of origin.

Ergot resistance

More than 2,500 germplasm accessions were screened to identify sources of resistance to ergot in pearl millet. Ergot resistance lines were developed by intermating relatively less-susceptible plants by pedigree selection (Thakur and Chahal, 1987).

Smut resistance

More than 1,500 accessions from germplasm working collection and 6,200 advanced breeding lines were screened to identify resistance to smut in pearl millet (Thakur and Chahal, 1987). All the advanced breeding lines were susceptible, but resistance was detected in several germplasm accessions originating from Nigeria, Senegal, Mali, Cameroon, Uganda, Lebanon and India. Selections from six germplasm accessions and four newly developed smut-resistant, agronomically elite lines showed consistently high levels of smut resistance for 1-6 years at six or seven locations in India and West Africa. These lines had across-location mean smut severities of less than 5% compared with 35% or more in the susceptible checks. These lines also were found to possess resistance to downy mildew in India.

Rust resistance

A dominant gene for rust resistance was found in 2696-14, a selection from the germplasm originating from Chad (Hanna *et al.*, 1985). A number of traits of economic importance were identified in the world collection of pearl millet. The seeds are available to any one who wants to use them. These should be more extensively used to broaden the genetic base to confer stability in high-yielding cultivars.

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PERFORMANCE IN RELATION TO POLLINATION SYSTEMS IN PEARL MILLET

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The relative efficiencies of three pollination methods, namely, bulk sibbing, random mating and self pollination in maintaining mean performance of pearl millet populations have been investigated. These pollination methods were applied to 16 varieties and synthetics and their influence was observed on nine characters related to flowering, plant height, head length and grain yield. The present study clearly demonstrated the superiority of random pollination, even in the absence of perfect isolation distance, in both, the maintenance of the mean performance of the varieties and relative ease in multiplication of several pearl millet populations at the same location.

Pearl millet is a highly cross-pollinated crop and inbreeding causes considerable depression for yield, vigour and viability (Pokhryal *et al.*, 1966; Khadr and El Rouby, 1978 and Rai *et al.*, 1985). This fact poses considerable difficulty in deciding an appropriate pollination method for maintaining the means and variance of pearl millet germplasm and breeding populations for their major attributes. The relative efficiencies of the three pollination methods to maintain the desirable level of mean performance of pearl millet populations have been examined in the present study.

MATERIALS AND METHODS

Varieties

Sixteen pearl millet open pollinated varieties (populations) of African and Indian origin (Table 1) were planted in a 200 m² adjacent plots in an off-season nursery with irrigation on January 10, 1981 at the Centre National de Recherches Agronomique (CNRA), Maradi, Republic of Niger, West Africa. The soil was sandy loam applied with N and P₂O₅ at 20 and 30 kg/ha as basal dose, respectively. The row to row and plant to plant distance was kept at 80 cm and 40 cm, respectively. After 20 days of planting, the excess plants were thinned to leave one plant per hill.

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Table 1. Pearl millet open pollinated varieties used in this study

Varieties	Developed by	Varieties	Developed by
ITMV 8006	ICRISAT-Niger	FS 546	ICRISAT-Burkina
ITMV 8007	" "	Ex-Bornu	IAR-Nigeria
ITMV 8008	" "	ITMV 8010	ICRISAT-Niger
ITMV 8009	" "	ICMS 7819	ICRISAT-India
IMMV 8018	" "	FS 547	ICRISAT-Burkina
ITMV 8024	" "	3/4 Ex-Bornu	INRAN-Niger
ITMV 8025	" "	ITMV 8003	ICRISAT-Niger
3/4 Ex-Bornu	INRAN-Niger	3/4 HK (tall)	INRAN-Niger

Pollination systems

Three pollination systems were practised for each of the varieties mentioned above.

(a) *Bulk sibbing* : On the dates when more than 50 selfed plants produced pollen, fresh pollen was collected from as many plants as possible, thoroughly mixed and equally distributed to 50 selfing bags. Fifty single earheads with fresh stigmas, from different plants, were pollinated each day with bulk pollen described above. The bulk sibbing was repeated for five days at one day intervals, thus resulting in 250 (5x50) bulk crossed earheads in each of the varieties.

(b) *Random pollination* : Natural random mating was allowed within each variety without control on the flow of the pollen.

(c) *Self pollination* : The heads of each plant which were covered by parchment paper bags before emergence of stigma, and from where pollen was collected for bulk sibbing, were bagged again to generate seeds by self pollination.

At maturity, 250 earheads were harvested and retained for each pollination system for each of the 16 populations. Heads were threshed and seed bulks of each pollination system for each of the populations were obtained.

Experimental design

Progenies of each of the 48 seed lots were evaluated for nine characters, namely, days to first flowering (DF 1), days to last flowering (DF 2), shortest plant's height, cm (PH 1), tallest plant height, cm (PH 2), mean plant height, cm (MPH), shortest head's length, cm (HL 1), longest head's length, cm (HL 2), mean head length, cm (HLM), and grain yield, g/20 m² (GYG) during the rainy season (June-Sept.) of 1981 at Maradi in a split-plot design. The sixteen varieties

Table 3. Means for varieties and pollination systems

Varieties	Mean of characters								
	DF-1	DF-2	PH-1	PH-2	PHM	HL-1	HL-2	HLM	GYG
1. ITMV 8006	44.0	59.1	156.3	214.3	177.9	29.5	52.5	38.6	2256
2. ITMV 8007	42.9	57.3	144.7	204.1	169.9	23.5	42.0	32.8	1844
3. ITMV 8008	46.7	59.1	136.5	215.1	170.4	23.3	40.7	32.4	2333
4. ITMV 8009	44.9	59.0	150.4	218.5	179.6	27.5	50.8	36.7	2422
5. ITMV 8018	44.0	56.8	134.5	222.2	181.7	24.4	47.9	35.1	2133
6. ITMV 8024	44.3	59.0	134.4	200.3	169.2	22.7	35.4	28.9	1756
7. ITMV 8025	45.7	58.8	143.3	207.1	177.8	24.1	43.5	32.6	2244
8. 3/4 Ex-Bornu	48.8	60.0	88.5	168.1	123.7	30.2	50.5	38.5	2056
9. FS 546	47.1	62.4	144.2	209.4	170.2	26.5	43.1	38.5	2822
10. Ex-Bornu	49.3	60.1	153.8	212.5	185.4	24.9	39.4	33.1	2311
11. ITMV 8010	48.7	59.3	159.9	228.1	202.2	24.5	44.2	33.4	2311
12. ICMS 7819	46.8	61.5	120.4	204.9	166.3	24.7	48.4	34.5	2144
13. FS 547	50.8	64.3	134.8	207.9	170.8	30.3	52.2	38.8	2189
14. 3/4 Ex-B (Tall)	48.8	58.7	141.1	225.7	189.6	25.2	47.9	35.9	2489
15. ITMV 8003	44.9	59.1	143.2	223.8	181.7	30.9	57.0	41.6	2178
16. 3/4 HK (Tall)	46.5	59.7	124.1	214.0	175.8	29.2	53.4	39.9	2144
SE of difference									
between means	1.5	1.3	10.2	12.3	10.9	1.7	2.3	1.5	230
LSD (p. 05)	3.1	2.7	20.8	25.1	22.2	3.4	4.8	3.0	470
Pollination systems									
1. Bulk sibbing	45.3	58.7	139.3	205.7	173.2	25.9	44.6	34.5	2271
2. Random									
pollination	46.5	59.7	144.4	217.6	179.6	28.4	50.7	37.6	2371
3. Self pollination	47.7	60.5	130.8	209.7	170.7	24.7	45.1	34.2	2040
SE of difference									
between means	0.44	0.36	4.24	4.04	3.02	0.57	1.08	0.53	78
LSD (P. 05)	0.88	0.72	8.47	8.07	6.04	1.13	2.16	1.06	156

The first flowering dates varied from 43 days for ITMV 8007 to 51 days for FS 547 whereas days to last flowering ranged between 57 days for ITMV 8018 to 64 days for FS 547. In general, the genotypes where flower initiation took place earlier, termination of flowering also took place in the same sequence. This clearly indicated the usefulness either of these characters to describe maturity cycle in pearl millet. The height of shortest plant varied from 88 cm for 3/4 Ex-

were used as main plots and pollination systems as sub-plot treatments. The trial consisted of 3 replications with the plot size of 20 m² for each sub-plot treatment. The hill planting as practised in Africa was done at a distance of 1 m x 50 cm and thinned to two plants/hill 20 days after planting. All the plants in the central two rows (10 m²) were observed.

RESULTS AND DISCUSSION

The analysis of variance of split plot design for the nine characters examined in this study is presented in Table 2. The variance due to differences among varieties was found to be highly significant for all the characters studied except for mean head length. The magnitude of variance due to varieties was higher for days to first flower than days to last flower and for shortest plant's height than tallest plant's height. The variance due to pollination system was also highly significant for all the characters with similar trend as for varieties. This indicated influence of pollination systems on the expression of populations for the characters examined.

Table 2. Analysis of variance for split plot design, varieties and pollination systems

Source	df	Mean sum of squares								
		DF-1	DF-2	PH-1	PH-2	PHM	HL-1	HL-2	HLM	GYG
Replication	2	1244.9	1476.6	19055.3	34860.1	24392.2	26.6	46.8	8.6	7472.5**
Varieties	15	46.8**	30.0**	2610.0**	1775.3**	2409.2**	71.9**	312.0**	102.6	547.1**
Error A	30	10.3	7.9	466.4	680.4	531.7	12.5	24.9	10.0	238.9
Pollination System	2	71.4**	41.5**	2252.3**	1757.5**	994.9**	177.5**	546.6**	170.7**	1385.6**
Interaction	30	9.7**	7.5**	488.2	717.9*	399.4*	24.2**	77.3**	23.6**	230.4*
Error B	64	4.7	3.1	431.9	392.6	219.4	7.7	28.1	6.8	146.0

*Significant at P= 0.05, ** Significant at P= 0.01

The population x pollination system interaction was highly significant for days to first flowering, days to last flowering, length of shortest head, length of longest head, mean head length, and grain yield. This component was significant at 5% probability for tallest plant height and mean plant height, and non-significant for the height of the shortest plant. The comparison of population x pollination system interactions with variance due to populations or due to pollination system as such indicated that the interaction component was much weaker than the main effects of population or pollination system. The means of populations averaged over pollination systems and means of pollination systems averaged over populations are summarised in Table 3.

Bornu to 160 cm for ITMV 8010, whereas tallest plant varied from 168 cm for 3/4 Ex-Bornu to 228 cm for ITMV 8010 with the mean plant height varying from 124 cm to 202 cm for these varieties, respectively. Therefore, any of these plant height traits can be used to describe the plant stature. The shortest head length varied from 22 cm for ITMV 8024 to 31 cm for 3/4 Ex-Bornu (tall). The longest head length of these varieties and their mean lengths were also in the same order. The close relation of different parameters used to describe characters such as days to flowering, plant height and head length in this study strongly supports high heritability for these characters. The grain yield varied from 1755 g/20 m² for ITMV 8024 to 2822 g/20 m² for 3/4 EX-Bornu with all other populations performing in between these.

The means of three pollination systems computed over populations for all the nine characters are also presented in Table 3. Comparison of means of different characters for the three systems of pollination indicated that the magnitude of the difference caused by the pollination systems was much lower than variability between populations themselves. Selfing and random pollination resulted into delaying first and last flowering by one and two days as compared to bulk sibbing. Plant height was adversely affected by random mating as the means of three plant height (PH 1, PH 2 and PHM) characters were highest for random mating. Self pollination appeared to have reduced the plant height.

Random pollination even without recommended isolation favourably increased head length attributes such as length of the shortest head, length of the longest head and mean head length. The crop resulting from random pollination showed longer head length compared to those produced by bulk sibbing and self pollination. For grain yield, random pollination also was found to be more favourable than the two other pollination systems employed. The study clearly demonstrated the merit of random pollination, even in the absence of perfect isolation, in maintaining the mean performance of the subjected pearl millet populations. Furthermore, random pollination was a relatively easier system to use.

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VARIATION IN ARRANGEMENT OF VEGETATIVE AND REPRODUCTIVE NODES ON LATERAL BRANCHES OF TWO VIRGINIA FORMS OF PEANUT GERMPLASM

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The arrangement of vegetative and reproductive nodes were examined on basal, primary and secondary branches of 75 accessions each of Virginia bunch and Virginia runner forms of cultivated peanut (Arachis hypogaea L. ssp. hypogaea Krap. et. Rig. var. hypogaea Krap. et. Greg.). The main axis was devoid of flowers (inflorescences) on all the plants of both the forms. The node sequence, in general, started with vegetative nodes on primary branches and reproductive nodes on secondary branches in both the forms. There was predominant occurrence of one to five reproductive nodes on secondary branches of both the forms. A few accessions had a continuous sequence of three to five reproductive nodes on secondary branches. On primary branches of Virginia bunch collection, three alternate irregular pairs of node sequences starting with vegetative nodes were recorded in 43.1% plants followed by four pairs in 25.9% plants, whereas in Virginia runner, four pairs (37.%) followed by three pairs (27.7%) were frequent. On the other hand, one pair starting with reproductive nodes on secondaries was predominant in 74.8% and 68.5% plants, respectively. The regular sequence of two vegetative alternating with two reproductive nodes was found on primaries of only 17.2% and 13.1% plants of Virginia bunch and Virginia runner, respectively. The alternate irregular sequences with all possible combinations numbering 111 on primary branches and 62 on secondaries were found in both the populations and thus, sequences with predominant occurrence could not be spotted. The wide variation for this trait in the sampled population, besides overlapping variation within and between the two forms confirmed that node sequence was controlled by polygenes. This trait may not be suitable for identification of Virginia genotypes in the primary gene pool of cultivated peanuts and also in differentiation between the two forms. The role of node sequence in breeding Virginias was also discussed.

The primary gene pool of cultivated peanuts (*Arachis hypogaea* L.) was classified into two sub-species, namely, *hypogaea* Krap. et. Rig. and *fastigiata*. Waldron based primarily on alternate and sequential branching pattern, respectively (Gregory *et al.*, 1951; Bunting, 1955; Krápovickas and Rigoni, 1960). The central axis in sub-species *hypogaea* never bears inflorescence directly (Stockton-Petit, 1895) and lateral branches bear two vegetative branches (nodes) alternating regularly with two reproductive branches (Bigi, 1950; Gregory *et al.*, 1951 and Bunting, 1955). This sub-species was further divided into two varieties, namely, *hypogaea* Krap. et. Greg.

and *hirsuta* Kohler (Krapovickas, 1968, 1973 and Gregory and Gregory, 1976). In var. *hypogaea*, two forms were further recognised, namely, Virginia bunch and Virginia runner (Krapovickas, 1968), commonly referred to in India as semi-spreading and spreading forms, respectively. The number and arrangement of vegetative and reproductive branches (nodes) served as a basis for varietal classification (Gregory *et al.*, 1973) but this system was found unsatisfactory for the intermediate forms collected from South America (Krapovickas and Rigoni, 1960). Recently wide variation was observed in vegetative and reproductive node number and its sequence on the basal primary branches of 100 Virginia runner accessions and arrangement of nodes upto 3 orders were described (Bhagat *et al.*, 1987). This investigation was further extended to both Virginia bunch and Virginia runner forms and all the nodes from base to the tip of the vegetative bud on primary and secondary branches were examined to confirm variation in the arrangement of vegetative and reproductive nodes in the germplasm collection.

MATERIALS AND METHODS

The national peanut germplasm collection of Virginia bunch and Virginia runner forms (numbering 2420 accessions) was field-planted at the onset of the regular monsoon on June 19, 1986 in an augmented block design (Federer, 1956). Each entry was grown in a 3 metre long row, spaced 60cm apart, with 10cm spacing between plants within a row. The crop was raised under rainfed conditions following recommended cultural practices. For this study, 75 accessions each of Virginia bunch and Virginia runner forms were randomly selected. At the time of harvest, 14-16 random plants of each accessions were examined for all vegetative (V) and reproductive (R) nodes (branches) on the main axis (n), primary (n+1) and secondary (n+2) branches.

The entire plant population of each form was separated into two parts, based on whether the first node was vegetative or reproductive on primary and secondary branches. Each sub population was further classified on the occurrence of alternate pairs of nodes (vegetative followed by reproductive or reproductive followed by vegetative). Finally, arrangement of nodes, both alternate irregular and alternate regular, was scored on primary and secondary branches of each form. Populations of 1175 and 1057 plants of 75 accessions each of Virginia bunch and Virginia runner, respectively, were studied.

RESULTS AND DISCUSSION

It was observed that all the plants did not bear flowers on the main axis. On primary branches of both the forms, the first two nodes were predominantly vegetative in 68.8 per cent plants and in 53.7 per cent plants, respectively (Table 1). The sequence starting with one vegetative node, however, was observed in 27.8 per cent and 35.1 per cent plants in Virginia bunch and Virginia runner collections, respectively. The sequence starting with reproductive node was scored in 3.4 per cent plants of Virginia bunch and in 11.2 per cent plants of Virginia runner collections. Similar observations were earlier reported in Virginia runner collection (Bhagat *et al.*, 1987).

Table 1. Plant population starting with vegetative (V) and reproductive (R) nodes on primary and secondary branches in two Virginia peanut germplasm

First order sequence	Nodes	Virginia bunch		Virginia runner	
		Primary branch	Secondary branch	Primary branch	Secondary branch
Starting with vegetative	1V	327 (27.8)	164 (13.9)	371 (35.1)	82 (7.8)
	2V	808 (68.8)	28 (2.4)	568 (53.7)	15 (1.4)
		1135 (96.6)	192 (16.3)	939 (88.8)	97 (9.2)
Starting with reproductive	1R	—	69 (5.9)	—	77 (7.3)
	2R	24 (2.0)	477 (40.6)	54 (5.1)	442 (41.8)
	3R	13 (1.1)	350 (29.8)	41 (3.9)	330 (31.2)
	4R	3 (0.3)	70 (6.0)	14 (1.3)	99 (9.4)
	5R	—	17 (1.4)	9 (0.9)	12 (1.1)
Total		40 (3.4)	983 (83.7)	118 (11.2)	960 (90.8)
		1175	1175	1057	1057

Figures in parentheses indicate percentage

On the other hand, the sequence starting with one to five reproductive nodes on secondary branches was observed in 83.7 per cent and 90.8 per cent plants of Virginia bunch and Virginia runner collections, respectively (Table 1). The sequence starting with vegetative nodes was, however, observed in 16.3 per cent plants of Virginia bunch and 9.2 per cent plants of Virginia runner collections. Among these, the sequence starting with two reproductive nodes was predominantly recorded in 40.6 per cent and 41.8 per cent plants in Virginia bunch and runner collections, respectively, followed by three reproductive nodes in 29.8 per cent and 31.2 per cent plants, respectively.

The sequence, in general, started with vegetative nodes on primary branches and reproductive nodes on secondary branches in both categories of the collections. In Virginia peanuts, the continuous occurrence of one to five reproductive nodes on secondary branches contribute directly towards increased number of pods and, thus, these two forms possess high productive potential than the other forms of cultivated peanuts. Higher contribution of pods formed on secondary branches in Spanish genotypes were also reported (Choudhary *et al.*, 1985; Shashidhar *et al.*, 1986). Though there was variation in number of reproductive nodes on secondary branches of both Virginia collections, a few accessions having a long sequence of three to five reproductive nodes on secondaries were available in the collection. Therefore, intensified screening of germplasm for the ideotypes having a continuous occurrence of reproductive nodes on secondaries with pods clustered around the tap root zone may be undertaken so that synchrony in pod maturity could be achieved in breeding programme, since the presently grown commercial Virginia varieties in India are devoid of this important trait and thus, the pod losses in farmers' field are high, ranging from 12 to 25 per cent.

There was variation between plants of each accessions and therefore, the entire plant population of each form was pooled for further grouping based on occurrence of alternate sequence pairs ranging from one to five (vegetative followed by reproductive or reproductive followed by vegetative nodes) from the base to the tip of primary and secondary branches, respectively. In Virginia bunch collection, three alternate pairs of sequence starting with vegetative nodes were recorded in 43.1 per cent plants followed by four pairs in 25.9 per cent plants while in Virginia runner, four pairs were observed in 37 per cent plants followed by three pairs in 27.7 per cent plants on primary branches (Table 2). One pair of node sequence was not found in both the forms on primary branches, whereas on secondary branches, it was recorded in 74.8 per cent plants of Virginia bunch and 68.5 per cent plants of Virginia runner collections. The presence of wide variation of higher order sequences ranging from 3 to 5 on primary branches and lower order 1 to 3 on secondary branches of both the forms was due to initiation of primary branches at 4-6 leaf stage followed by secondary branches on it at latter stages of the plant growth. It was further observed that the occurrence of higher order sequences in Virginia runner and lower order in Virginia bunch accessions reflected in late maturity of Virginia runner (135-150 days) as against 115-125 days in Virginia bunch accessions.

As reported, the arrangement of nodes in Virginia forms should have two vegetative alternating with two reproductive nodes uniformly on the primary and

Table 2. Number of plants with alternate (irregular and regular) sequence pairs of one to five order in Virginia bunch and Virginia runner peanut germplasm

Sequence pairs	Virginia bunch				Virginia runner			
	Primary branch		Secondary branch		Primary branch		Secondary branch	
	Number of combinations	Number of plants	Number of combinations	Number of plants	Number of combinations	Number of plants	Number of combinations	Number of plants
<i>Alternate irregular</i>								
(1) Starting with vegetative nodes								
1 pair	—	—	6	104 (8.8)	—	—	6	50 (4.7)
2 pairs	16	84 (7.2)	12	64 (5.5)	—	—	4	23 (2.2)
3 pairs	31	506 (43.1)	5	7 (0.6)	28	293 (27.7)	6	14 (1.3)
4 pairs	25	304 (25.9)	—	—	28	391 (37.0)	—	—
5 pairs	20	39 (3.3)	—	—	20	117 (11.1)	—	—
(2) Starting with reproductive nodes								
1 pair	—	—	16	879 (74.8)	—	—	14	724 (68.5)
2 pairs	8	11 (0.9)	20	100 (8.5)	—	—	23	205 (19.4)
3 pairs	7	25 (2.1)	3	4 (0.3)	17	76 (7.2)	11	31 (2.9)
4 pairs	4	4 (0.3)	—	—	14	38 (3.6)	—	—
5 pairs	—	—	—	—	4	4 (0.3)	—	—
	111	973 (82.8)	62	1158 (98.5)	111	919 (86.9)	64	1047 (99.0)
<i>Alternate regular</i>								
1 pair	—	—	1	16 (1.4)	—	—	1	8 (0.8)
2 pairs	1	15 (1.3)	1	1 (0.1)	—	—	1	2 (0.2)
3 pairs	1	126 (10.7)	—	—	1	46 (4.4)	—	—
4 pairs	1	56 (4.8)	—	—	1	62 (5.9)	—	—
5 pairs	1	5 (0.4)	—	—	1	30 (2.8)	—	—
	4	202 (17.2)	2	17 (1.5)	3	138 (13.1)	2	10 (1.0)

Figures in parentheses indicate percentage

Table 3. Number of plants showing major alternate irregular node sequence on the primary and secondary branches of two Virginia peanut germplasm

Order of sequence pairs	Virginia bunch		Virginia runner	
	Primary branch	Secondary branch	Primary branch	Secondary branch
<i>a) Starting with vegetative nodes</i>				
(1V+1R)	-	21 (1.8)	-	-
(1V+2R)	-	46 (3.9)	-	26(2.4)
(1V+3R)	-	21 (1.8)	-	-
(2V+2R) + (1V+2R) + (2V+2R)	73 (6.2)	-	34 (3.2)	-
(2V+3R) + (2V+2R) + (2V+2R)	67 (5.7)	-	37 (3.5)	-
(2V+2R) + (1V+2R) + (2V+2R) + (2V+2R)	77 (6.5)	-	57 (5.4)	-
<i>b) Starting with reproductive nodes</i>				
(3R+2V)	-	191 (16.2)	-	144 (13.6)
(2R+2V)	-	228 (19.4)	-	169 (16.0)
(3R+2V) + (2R+2V)	-	23 (1.9)	-	43 (4.1)
(2R+2V) + (2R+2V)	-	-	-	59 (5.6)

Figures in parentheses indicate percentage

secondary branches (Bigi, 1950; Gregory *et al.*, 1951 and Bunting, 1955), but in the present material this regular sequence was recorded on primary branches of only 17.2 per cent plants of Virginia bunch and 13.1 per cent plants of Virginia runner and on secondary branches of only 1.5 per cent and 1 per cent plants, respectively (Table 2). On the other hand, alternate irregular sequence numbering 11 on primary branches and about 62 combinations on secondary branches with all possible combinations of vegetative (1-3) and reproductive (1-5) nodes were recorded in majority of plants of both the forms (Table 2). In these highly variable populations, sequence which occurred in more than 20 plants are listed in Table 3. Among these, only one order sequence starting with reproductive nodes, namely, 2R+2V and 3R+2V occurred often, respectively, on secondary branches of 19.4 per cent and 16.2 per cent plants of Virginia bunch and 16 per cent and 13.6 per cent plants of Virginia runner accessions.

The majority of the sampled Virginia accessions included in this study constitute from secondary (29) and tertiary (116) centres of diversity and the genetic variation in this trait might have generated either by infrequent cross pollination in nature (Stone, 1973) or inter-sub-specific hybridization attempted by the breeders followed by purposeful selection for desired intermediate forms. The arrangement of vegetative and reproductive nodes on both primary and secondary branches of two Virginia populations appeared quantitative in nature confirmed earlier (Wynne, 1975). Further, the wide variation within each accessions and overlapping variation between the two forms for this trait made differentiation of Virginia bunch and runner forms based on node sequence difficult. Thus, this trait may not be considered suitable for identification of Virginia genotypes in the primary gene pool of cultivated peanuts. However, of course, accessions of these forms were devoid of flowers (inflorescences) on the main axis and may continue to be a basic characteristics in botanical classification.

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GENETIC RESOURCES FOR VARIETAL IMPROVEMENT IN FODDER OATS

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In India, oats have been increasingly gaining importance as a good fodder and feed resource. This obviously necessitates its genetic improvement for which a wider genetic base is an essential pre-requisite. In this paper, an attempt has been made to highlight the need for new plant genetic resources and indicate the germplasm resource centres. Sources of genes for specific traits, viz., production traits, quality traits, disease resistance, drought resistance, winter hardiness, lodging resistance, photo-insensitivity, high growth rate, and high physiological efficiency have been pointed out.

Oats have recently assumed considerable importance in India for its fodder value for livestock and as animal feed particularly for calves and young stock, horses, poultry and sheep. With the advent of intensified dairy industry in the country, especially with the cross-bred animals, the oat fodder, among others, is progressively figuring for its improvement, attracting attention of plant breeders on one hand and the crop husbandry and livestock rearing workers on the other.

The success of any breeding programme depends on the available genetic base. Assemblage of a large and genetically diverse genepool including wild taxa, especially from centres of origin and the centres of the maximum diversity becomes important in isolating/developing desirable types. In this paper, an attempt has been made to project the available information on the germplasm which may prove to be very useful in the development of new varieties for various purposes and situations.

Need for new plant genetic resources

The new genepool resources are required to be exploited for particular purposes and therefore the objectives with respect to the development of specific varieties should be well defined. It is of utmost importance to know about the problems and specific needs with particular reference to varied farming systems embracing oat as a fodder component. Forage based livestock feed of good quality needs to be produced under varied situations as (i) intensified fodder production system for dairying, (ii) integration of fodder crops with food/cash crops and horticultural crops for mixed farming under irrigated and dry land conditions, (iii) forage production under specific climatic and edaphic situations.

Greater emphasis is given to high tonnage of fodder in most breeding programmes, although the importance of nutritive value of forage also caught attention of forage oat breeders in the recent past. There is an urgent need to develop forage oat

varieties capable of producing high dry matter yield per unit area and time coupled with high nutritive value. Of course, breeding work related to disease resistance, wider adaptation and responsiveness to higher inputs also deserves due consideration. Under situations of excessive production during normal growing season, the surplus fodder needs to be conserved as silage or hay and the varieties must possess specific traits required for efficient conservation. Suitable plant types are needed for different cutting management systems in monoculture and for mixed cropping with leguminous fodders. Thus, the breeding strategies need to be reoriented in the above directions with particular emphasis on exploitation of new sources of genes for specific traits.

Germplasm resource centres

Sizeable oat germplasm collections are available at Plant Genetics and Germplasm Institute, U.S. Department of Agriculture, Beltsville, Maryland (U.S.A.); Research Station Ottawa, Ontario (Canada) as well as in U.S.S.R. and Israel. In India, a good oat germplasm collection is available at the Indian Grassland and Fodder Research Institute, Jhansi; G.B. Pant University of Agriculture and Technology, Pantnagar; Haryana Agricultural University, Hisar; Punjab Agricultural University, Ludhiana; Himachal Pradesh Krishi Vishwa Vidyalya, Palampur; Indian Agricultural Research Institute, New Delhi; and the National Bureau of Plant Genetic Resources, New Delhi. Free exchange of material between different agencies will help the breeders for quick development of better varieties. It may also be mentioned that Mediterranean basin is considered as the homeland of *Avena* species. An appropriate effort for further exploration in this region will provide more diverse material including species collection in future.

Sources of genes for specific traits

Besides the two important cultivated hexaploid species, *A. sativa* and *A. byzantina* grown for grain as well as fodder, many wild species have been brought under cultivation in different parts of the world due to their usefulness for forage and grain production. The important species grown for fodder are *Avena sterilis* in Mediterranean region and south-west Asia; *A. fatua* in south-west Asia; *A. abyssinica* in Ethiopia, *A. barbata* in Mediterranean region and Iran, *A. brevis* in southern Europe; *A. strigosa* in Mediterranean region, *A. wiestii* in U.A.R. and Iran and *A. ventricosa* in Algeria. The useful genes for different characters are distributed in different species. Many wild *Avena* species may serve as a useful source of germplasm for oat improvement. The new exotic germplasm of different diploid, tetraploid and hexaploid species assembled from various sources has been screened at the Indian Grassland and Fodder Research Institute, Jhansi and the new sources of useful genes have been located for their further exploitation (Bhag Mal, 1985).

1. Sources of genes for production traits

Desirable genes for specific production traits are located in different cultivars. Varieties Rapida and Montezuma, developed in U.S.A., Tarahumara in Mexico and Flamingsnova in West Germany are good sources of earliness. The variety Scott

from U.S.A. has been observed to possess genes for tallness and leafiness. It produces 10-11 leaves per tiller with about 40-45 cm length and 8.00 cm breadth and may serve as a good donor for leaf number and leaf size. The varieties Houston, Norwin, Coronado and Cortez are capable of high forage production in U.S.A. The variety Saturn has been specifically bred and released for forage production in Czechoslovakia (Sebesta and Cervanka, 1979). The variety Blackbutt was released by New South Wales Deptt. of Agricultural for heavy grazing. It is a late maturing variety like Algerian.

Amongst the wild species, *A. abyssinica* and *A. canariensis* are important for earliness (Table 1). The genes for tallness are distributed in *A. sterilis*, *A. ludoviciana* and *A. strigosa* and for tiller number in *A. hirtula*, *A. prostrata* and *A. damascena*. Cultivars from *A. sterilis*, *A. nuda* and *A. chinensis* may contribute genes for high leaf number, leaf length and leaf width. The desirable genes for seed size are located in *A. magna* and for spikelet number in *A. nuda*, *A. pratensis*, *A. abyssinica* and *A. brevis*. The studies at IGFR, Jhansi revealed that EC 130639 of *A. sterilis* possessed good tillering (11-12), plant height (150 cm), leaf number (9.0), leaf length (44 cm) and dry matter yield per plant (100 g). Likewise, EC. 108467 of *A. nuda* was observed promising for leaf length (44.2 cm), leaf width (2.3 cm), spikelet number (69.8) and seed yield per plant (30.0 g). Two accessions, viz., EC 131287 and 6409 of *A. magna* were observed to have very bold seeds with 1000 seed wt. of 61.0 g and 62.0 g, respectively. These accessions belonging to different species may be used as the donors of genes for traits in the hybridization programme.

2. Sources of genes for forage quality traits

The most important requirement of nutritive fodder is that it should be able to supply sufficient energy and protein for animal growth (Milford, 1964). The most important and relatively simple measure of energy is provided by digestibility of dry matter. Other parameters which determine the forage quality are neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose, hemicellulose, lignin and silica. A number of varieties with high protein percentage e.g., Dal, Goodland, Otee, Wright, Marathon and Spear have been developed and released in USA (Frey, 1979). The genes responsible for high protein % in these varieties are from *A. sativa*. Protein content of seed of *A. sterilis* has been reported from 17 to 35%. Further, studies have shown that genes for high protein content from *A. sterilis* and *A. sativa* are complementary which suggests that they can be combined to give a protein per cent higher than present in either of the species. Similar studies need to be conducted for foliage protein.

Studies conducted at Indian Grassland and Fodder Research Institute, Jhansi indicated that the genes for high foliage protein are distributed in *A. sterilis*, *A. magna*, *A. ludoviciana*, *A. maxima* and *A. abyssinica* and for dry matter digestibility in *A. maxima*, *A. ludoviciana*, *A. magna* and *A. abyssinica* (Bhag Mal, 1985). Likewise, genes for other quality traits are distributed in different species (Table 2).

The genotypes EC 108434 and EC 131312 of *A. abyssinica* possessed high crude protein (18-19%), high dry matter digestibility (71-73%) and comparatively

Table 1. Sources of genes for desirable production traits in *Avena* species

Species	Earliness	Plant ht.	Tiller No.	Leaf No.	Leaf length	Leaf breadth	Panicle length	Spikelet No.	100 seed weight
<i>A. sterilis</i>		x		x	x	x			
<i>A. nuda</i>				x	x	x		x	
<i>A. chinensis</i>				x				x	
<i>A. ludoviciana</i>		x							
<i>A. pratensis</i>								x	
<i>A. vaviloviana</i>							x		
<i>A. barbata</i>					x		x		
<i>A. magna</i>									x
<i>A. abyssinica</i>	x						x		
<i>A. brevis</i>							x		
<i>A. strigosa</i>		x							
<i>A. hirtula</i>			x						
<i>A. prostrata</i>			x						
<i>A. damacena</i>			x						
<i>A. longiglumis</i>						x			
<i>A. canariensis</i>	x								

x - indicates the presence

Table 2. Sources of genes for forage quality traits in *Avena* species

Species	Crude protein	IVDMD	NDF	ADF	Cellulose	Hemicellulose	Lignin	Silica
<i>A. sterilis</i>	x				x			x
<i>A. fatua</i>					x			
<i>A. maxima</i>	x	x			x			x
<i>A. ludoviciana</i>	x	x						x
<i>A. pratensis</i>						x	x	
<i>A. vaviloviana</i>						x		x
<i>A. barbata</i>				x			x	x
<i>A. magna</i>	x	x						x
<i>A. abyssinica</i>	x	x	x	x				
<i>A. brevis</i>							x	
<i>A. ventricosa</i>				x			x	

x - indicates the presence

low NDF (50-52%), low lignin (1.6 - 2.9%) and low silica (1.1 - 1.2%). Likewise, EC 131287 of *A. magna* possessed high protein (19.10%), high digestibility (71.2%) and low lignin (0.69%). EC 130639 and EC 130640 of *A. sterilis* exhibited high crude protein (17-18%), moderately low lignin (3.0 - 3.3%) and low silica (0.73%), whereas EC 130641 and CAV 3117 possessed high crude protein (18.2 - 18.4%) along with high digestibility (68.6 - 69.9%) and low silica (1.67 - 1.69%). These could be used as sources of genes for specific quality traits in the fodder oat improvement programme.

3. Sources of disease resistance

Until recently, the main emphasis has been on the exploitation of race specific resistance conferred by major genes while in those cases where a pathogen has developed a race spectrum, the problem has been to find a succession of new resistance genes (Lawes, 1971). Greater attention is now directed to the use of non-specific (horizontal) resistance. New sources of genes are to be located for their effective transfer to the cultivated types. The resistant varieties for crown rust are Houston, Norwin, Coronado, Cortez, Dodge, Gerland from USA and Fidler from Canada. Other varieties possessing high degree of resistance were Fidler for stem rust, Fidler and Blackbutt for smut and Mostyn for powdery mildew.

A wealth of untapped but useful genes are available in lesser known oat species and their exploitation would be desirable. The species having cultivars possessing resistance genes for all the three important diseases, namely, stem rust, crown rust and mildew are *A. strigosa*, *A. barbata* and *A. sterilis*. Sources of genes for resistance to these important diseases have been located in many other species (Table 3). Use of *A. hybrida*, *A. sterilis*, *A. fatua* and *A. occidentalis* will be helpful in transferring resistance genes for Barley Yellow Dwarf Virus. Mildew resistance from hexaploid *A. sterilis* and *A. fatua* can be readily introduced by backcrossing. However, the transfer of genes for diploid and tetraploid species into cultivated species is more difficult due to strong sterility barriers which are required to be overcome.

**Table 3. Sources of genes for disease resistance in wild
Avena species**

Species	Resistance			
	Stem rust	Crown rust	Mildew	BYDV
<i>A. sterilis</i>	R	R	R	R
<i>A. fatua</i>	R			R
<i>A. ludoviciana</i>			R	
<i>A. occidentalis</i>				R
<i>A. barbata</i>	R	R	R	R
<i>A. magna</i>		R		
<i>A. abyssinica</i>		R		
<i>A. hirtula</i>			R	
<i>A. longiglumis</i>	R			
<i>A. strigosa</i>	R	R	R	R
<i>A. ventricosa</i>				
<i>A. prostrata</i>			R	

R - indicates resistance

BYDV - Barley Yellow Dwarf Virus

A genotype of *A. barbata* collected in Algeria has been reported to be resistant to all prevalent races of mildew in U.K. (Thomas *et al.*, 1975) which may serve as a good source of resistance genes. A considerable reservoir of resistance to crown rust flora has also been reported in *A. fatua*, *A. ludovicinana* and *A. barbata* in New South Wales (Brouwer *et al.*, 1981).

4. Sources of drought resistance

Development of oat varieties tolerant to drought conditions would become necessary if oat cultivation is to be extended to areas which do not have irrigation facilities. Little work appears to have been done in this direction. The studies on chlorophyll stability index for measuring drought resistance revealed that IGFRI 3021 having the lowest index (2.0) as against (16.3) of Kent was observed to with stand high temperatures (Yadava *et al.*, 1975). Other cultivars of *A. sativa* and *A. barbata* possessing low stability index were also identified. EC 96559 showed better performance under water-stress conditions (Manchanda and Ghosh, 1978). Such sources could be utilized for transferring drought resistance genes to otherwise high yielding types.

5. Sources of winter hardiness

There is a need to develop winter hardy oat varieties in view of its cultivation gradually extending to colder regions of the country. The varieties Bronco, Mustang, Norwin and Blackbutt possess considerable winter hardiness and may be used as donors of genes for winter hardiness. *A. hybrida* a wild hexaploid oat collected from Wakhan region of Afganistan at an attitude of 2300m, possesses winter hardiness which may be incorporated into *A. sativa*. Promising cultivars of *A. fatua* and *A. sterilis* possessing winter hardiness may also be exploited.

6. Sources of lodging resistance

Under high input situations, considerable degree of damage is expected to be caused due to lodging which is primarily attributed to poor straw strength and, therefore, attention needs to be paid towards the development of lodging resistant varieties. The varieties, namely, Houston, Norwin, Coronado, Cortez, Hermes and Blackbutt possessing greater straw strength may be used as donors for developing lodging resistant varieties.

7. Genes for photo-insensitivity

In an attempt to locate genes for insensitivity to photoperiod in diploid, tetraploid and hexaploid *Avena* species, Sampson and Burrows (1972) observed that materials of northern region were very sensitive to day length, the mediterranean diploids were moderately sensitive and tetraploids (*A. abyssinica* and *A. barbata* group) were insensitive. They further reported that Rapida (*A. sativa*) and CWS (*A. byzantina*) were slightly sensitive to day length suggesting the possibility of using them as parents. Med. 147, a strain of *A. byzantina* collected in the Mediterranean area is a good source of day length insensitivity (Zillinsky, 1971).

8. Genes for high growth rate

The most significant source of genetic variability for this trait is the weedy species *A. sterilis*. Genes for high growth rate have now been introgressed from *A. sterilis* into good *A. sativa* genotypes. High growth rate is a polygenically governed trait with estimated effective 6-8 factor pairs (Frey *et al.*, 1979).

9. Breeding for high physiological efficiency

Development of suitable plant types possessing high physiological efficiency is necessary to meet the requirements of different farming systems. Erect plant type with no or low droopiness of leaves would be better for intercropping of oats with other crops, whereas cultivars with prostrate growth habit would be preferred for grazing purposes. The genotypes CAV 2699 and EC 131300 of *A. byzantina*, CAV 3117 of *A. sterilis*, 6415 B of *A. rousse* and 6416 of *A. abyssinica* exhibited erect growth habit along with almost erect leaves and could be used as donors for these traits. EC 130639 of *A. sterilis*, CAV 227 and CAV 357 of *A. barbata* possessing prostrate growth habit could be useful in developing pasture oats.

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EVALUATION OF RICE GERMPLASM FOR BLAST AND QUALITY ANALYSIS IN SOME RESISTANT DONORS

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Evaluation of three hundred and five diverse rice (Oryza sativa L var. indica) genotypes against leaf blast led to the identification of 16 resistant and 28 tolerant cultures. Among 125 gora rices, only 10 showed tolerant reaction; none exhibited complete resistance. Six upland rice cultivars (Brown gora- HRC 14, Black gora - HRC 358, Kalakeri, Bhattadhan, N 22 and Dular) appeared to possess durable resistance. Quality analysis of 15 resistant donors suggested that some of them like Salumpikit, Bhattadhan, Kalakeri, CR 143-2-2, Brown gora HRC 14 and Khao Vano Veri possessed multiple desirable quality traits and hence should preferably be used in the varietal improvement programme to enhance the possibility of recovering segregants simultaneously improved for blast resistance and quality.

Blast caused by *Pyricularia oryzae* Cav. is the major disease of rice in the rainfed upland agro-ecological situation. Upland rice is predominantly grown with traditional varieties. The spread of high yielding varieties with increased use of nutrients, especially nitrogen, results in the increase of blast incidence. Since host resistance is better and economic than chemical control to combat diseases, breeding for stable, blast resistant cultivars is important. Sources of resistance to blast available in high yielding cultivars are narrow and can be traced in donors like Tetep and Tadukan. However, it has not been possible to transfer the whole complement of genes as they have been often broken down. (Ou, 1985).

Efforts to identify appropriate donors for developing blast resistant cultures need to be intensified. A wider genetic base and its accumulation is essential in the varietal improvement programme to avoid the danger of genetic vulnerability. Hence, evaluation of diverse native landraces, elite cultivars/strains, exotic and indigenous collections was undertaken. Further, it is desirable to have donors combining high resistance with good agronomic base and superior grain/cooking quality so as to have breeding lines simultaneously improved for several traits. The present paper reports systematic blast diseases screening and quality traits of a few resistant donors at this station.

MATERIALS AND METHODS

Three hundred and five diverse rice genotypes (125 'gora', 112 indigenous, 9 exotic and 59 improved lines and cultivars) were evaluated for blast resistance during wet seasons of 1986 and 1987. The nurseries were raised in August-September as natural air borne inoculum was adequate and weather favourable for disease development (Fig. 1). The test entries were sown in one-row plots in an augmented design with resistant (Rasi) and susceptible (HR 12) checks after every 50 test entries. Conventional uniform blast nurseries were slightly modified to include an additional spreader variety (Brown gora) that is partially killed by blast but provides inoculum for extended periods of time. This local susceptible variety has early seedling vigour and develops profuse foliage which helps to trap and conserve moisture within the canopy to accelerate disease spread. The nurseries were irrigated during dry spells in the afternoons. Evaluation of germplasm started in the nursery with disease appearance and continued until the susceptible checks were completely killed (usually one month after sowing or even further depending on epidemic development). Scoring was done following Standard Evaluation System for rice (Anonymous, 1988).

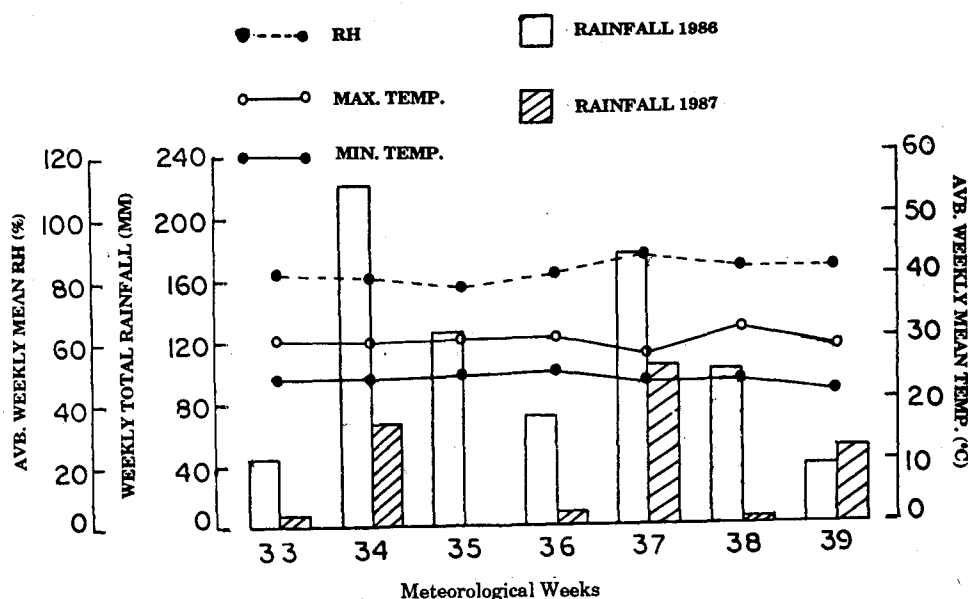


Fig. 1. Average weather conditions during blast nursery test (1986-87) at Hazaribag

Nine blast resistant (consistent score of 3 or less) and six partially resistant genotypes were direct seeded (10 g/m^2) during 1988 wet season at moderate fertility level (40 : 20 : 20 NPK) in three-row plots with 20 cm row to row spacing to study the quality traits of these genotypes. These were analysed by a composite sample from the central row and observations were recorded on hulling, milling and head rice recovery (Govindaswamy and Ghosh, 1969), milled

kernel length and breadth using dial micrometer (Mitutyo, Japan), alkali digestion value (Little *et al.*, 1958), amylose content (Juliano, 1971), water uptake and volume expansion (Beachell and Stansel, 1963) and kernel elongation (Azeez and Shafi, 1966).

RESULTS AND DISCUSSION

In the present study, 16 genotypes (5.2%) exhibited resistant reaction (8 were exotic and 8 improved) and 28 test entries showed moderately resistant reaction (Table 1). Among the entries with scores of 3 or less, Tres Marias, Salumpikit, IAC 25 and CR 143-2-2 appeared to have broad spectrum vertical resistance as they were observed to be resistant in diverse agro-environments. These genotypes could be utilized as donors in the rice breeding programme for race specific resistance.

Table 1. Rice genotypes with qualitative and quantitative resistance to blast

Reaction	Frequency of genotypes		Genotypes
	Number	Percentage	
0	0	0	-
1	0	0	-
2	3	0.98	CR 143-2-2, Rohini, Mannuthy 24-20
3	13	4.26	Annapurna, CR 544-1-1, CR 544-1-6, CR 544-1-14, Aditya IAC 25, IAC 1131, MI 48, Dao Pao, Salumpikit, Khao Vano Veri, Lai Iwang Tres marias
4	10	3.28	CR 544-1-2, RR 145-22, CR 636-7, CR 635-9, CR 666-362, CR 666-59, CR 666-68, CR 666-862-7, RP 2219-7964-22, RP 2346-2325-148-7
5	18	5.90	Sukhawel 20, HRC 101, 113, 146, 154, 231, Br. gora 270, 280, 408, 409, RP 2217-8209, 42, Lalnakanda 41, HRC 83, 85, 127 ARC 11775, HRC 14, RR 167-982
6	261	85.86	

The development of cultivars with durable or horizontal resistance may be another way for blast management. This approach would be desirable as there is a risk of breakdown of vertical resistance because of the highly variable nature of the blast pathogen. Cultivars with durable resistance have been suggested as an economic proposition in an area with subsistence farming (Crill, 1982). Identification of donors for durable resistance is difficult because durability can only be recognised retrospectively after a cultivar has been grown for many years in an agro-ecosystem where disease is prevalent above the economic threshold level (Bonman and Mackill, 1988). It is also suggested that cultivars with

consistent rating between 4-6 with overall average not exceeding 5.5 may have a good level of durable (quantitative) resistance (Anonymous, 1988). The findings of the present investigation coupled with earlier work of (Variar and Maiti, 1988) confirmed that six indigenous upland rice cultivars, viz., *N 22*, *Dular*, *Bhattadhan*, *Kalakeri*, *Brown gora* and *Black gora* possessed durable resistance. These cultivars are characterised by moderate diseases in early growth stages followed by rapid recovery and adult plant resistance. They have been grown in sufficiently large areas for many years in disease prone environments but under sub-optimal nutrient levels. Agronomic value of such resistance under optimal nutrient management needs to be evaluated and may prove valuable if combined with broad spectrum vertical resistance.

One of the approaches that could be adopted in the management of blast with host resistance is the incorporation of major gene(s) into cultivars with good agronomic base which provide complete protection to the cultivars against prevalent pathogenic race(s) – Vertical Resistance. Since cultivar development with wide genetic base is essential in a breeding programme, it is useful to have donors with multiple desirable traits. Hence, the evaluation of blast resistant donors for quality characteristics is of significance. Quality characteristics of the blast resistant genotypes (score 3 or less) are presented in Table 2. There was not much variation in the hulling and milling out-turn of the donors but the head rice yields varied substantially. *Salumpikit*, *Rohini* and *CR 143-2-2* had high head rice yields. Only *CR 544-1-14* exhibited LS grain whereas *Rohini*, *Khao Vano Veri* had LB grains (Table 2). Only three blast resistant cultures possessed desirable level of intermediate gelatinization temperatures (alkali score of 4-5). Except *Khao Vano Veri*, *Salumpikit* and *CR 143-2-2*, donors exhibited intermediate amylose content. Besides blast resistance, *Salumpikit Annapurna* and *Khao Vano Veri* also provided good sources for high water uptake (Table 2). *Salumpikit*, *CR 143-2-2* and *Annapurna*, *Kalakeri* and *Brown gora* showed a fairly high degree of kernel elongation whereas maximum volume expansion was recorded for *Mannuthy 24-20*.

Of the six possible donors for durable resistance, *Brown gora* and *Kalakeri* could also be useful sources for grain weight, while *Dular*, *N 22* and *Bhattadhan* had high head rice yields in addition to partial resistance. *Bhattadhan* and *Kalakeri* also exhibited high water uptake - a desirable cooking quality trait and high volume expansion, a valuable cooking quality character was observed in *Brown gora* and *Dular* (Table 3).

Blast resistant donors identified in the present study can be used in the development of improved rice cultivars with built-in resistance. However, enhancing the chances of getting segregants with improved resistance and grain/cooking quality, donors like *Salumpikit*, *Annapurna*, *Khao Vano Veri*, *CR 143-2-2*, *Kalakeri*, *Bhattadhan* and *Brown gora* (HRC 14) should be utilised in the breeding programme.

Table 2. Physico-chemical and cooking quality attributes of blast resistant donors in rice (*Oryza sativa* L.)

Character	Cultivars (Donors)								
	1	2	3	4	5	6	7	8	9
Hulling (%)	74.10	76.40	78.10	75.30	76.90	76.30	75.20	76.00	71.60
Milling (%)	68.50	71.30	73.10	70.30	71.70	68.90	69.80	70.40	66.70
Head rice recovery (%)	65.60	59.00	63.00	45.50	56.50	36.40	32.40	35.90	31.40
Milled kernel length (mm)	5.18	5.52	6.54	5.47	6.72	6.02	6.22	6.05	6.30
L : B ratio	1.90	2.22	2.55	2.15	2.60	2.24	2.47	2.45	3.00
Alkali digestion value	3.50	3.50	2.50	3.50	5.50	5.50	2.50	2.50	2.50
Amylose content	19.10	19.20	22.80	20.91	16.70	20.60	22.44	21.60	20.30
Water uptake	365.00	235.00	265.00	340.00	330.00	303.00	275.00	280.00	288.00
Volume expansion	4.00	3.70	4.00	3.70	3.70	4.10	3.85	3.70	3.70
Kernel elongation	2.05	1.74	1.62	1.75	1.49	1.56	1.58	1.59	1.56

1. Slaumpikit (HRC 20), 2. CR 143-2-2 (HRC 297), 3. Rohini (HRC 4248), 4. Annapurna (HRC 431), 5. Khao vano veri (HRC 505), 6. Mannuthy 24-20 (IET) 11403, 7. CR 544-1-1 (IET 11409), 8. CR 544-1-6 (IET 11413), 9. CR 544-1-14 (IET 11415).

Table 3. Quality characteristics of rice genotypes with durable resistance in rice (*Oryza sativa* L.)

Character	Genotypes	Br. gora (HRC 14)	Bl. gora (HRC 358)	Kalakeri (HRC 17)	Bhattadhan (HRC 19)	N 22 (HRC 4)	Dular (HRC 21)
1000 grain weight (g)		28.50	24.40	28.20	25.60	21.40	23.80
Hulling (%)		74.10	72.80	74.10	75.30	74.20	70.70
Milling (%)		66.90	67.10	64.20	65.90	69.10	63.70
Head rice recovery (%)		49.30	40.00	43.10	58.00	60.50	58.80
Milled kernel length (mm)		5.68	5.29	5.72	5.51	4.94	6.08
L : B ratio		2.08	2.17	2.21	1.93	2.10	2.59
Alkali digestion value		3.10	2.50	3.50	3.50	2.50	3.50
Amylose content (%)		19.10	20.90	19.90	19.60	17.50	19.10
Water uptake (ml)		340.00	330.00	345.00	395.00	300.00	335.00
Volume expansion		4.00	3.70	3.60	3.60	3.70	4.00
Kernel elongation		1.76	1.62	1.81	1.63	1.62	1.48

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INHIBITION OF SEED GERMINATION BY THE ENDOCARP IN *NEEM* (*Azadirachta indica* A. JUSS.)

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The endocarp inhibited the seed germination in neem (Azadirachta indica A. Juss.) by delaying the initiation of germination and lowering the germination percentage to about three to four times. The endocarp not only acted as a physical barrier but also seemed to contain some inhibitory substance (s) which possibly acted as a metabolic barrier during seed germination.

Neem (Azadirachta indica A. Juss.) is native to India and has found several applications in indigenous medicines, soaps and insecticides. Although neem tree provides abundant fruits seasonally, yet limited work has been done on the germination aspects of neem seed (orthodox in nature) especially the role of endocarp during seed germination. Only adverse effect of temperature on germination of neem seeds above 30° C had been reported (Ezumah, 1986). It was not clearly understood whether endocarp prevented germination entirely or delayed it considerably (Roberts *et al.*, 1984). This paper reports the results of the investigations to determine the effect of various factors like light, water and endocarp on seed germination in neem.

MATERIALS AND METHODS

Ripe yellow fruits naturally fallen on the ground and shown to be physiologically mature with maximum germination capacity (Maithani *et al.*, 1989) were collected from neem trees in the campus area of the Indian Agricultural Research Institute, New Delhi. The seeds were pressed out from the fruits and the pulp was removed by water washings. The seeds were given hot water treatment at 47° C for 10 minutes, and treated with fungicide (captan 0.5%). Seeds were air dried and packed in polythene bags before storing at room temperature till use.

For germination studies, both intact seeds and excised seeds (without endocarp) were plated in between the folds of moistened filter paper in plastic petridishes of 11 cms diameter and maintained at 27° C with 16 hour photoperiod (Ezumah, 1986). Germination was recorded based on emergence of well formed 1 cm long radicle. Three replicates of 50 seeds each were used per treatment. To determine the water uptake, three replicates of ten weighed seeds each with/without endocarp were imbibed in distilled water at 30° C and the increase in their weights was recorded at regular intervals until 24 hours when the first sign of germination was visible in seeds without endocarp.

The effect of light was studied by plating 50 seeds for germination under continuous light after removal of endocarp and controls were maintained in dark at

27° C. Scarification of the seeds was done by removal of the endocarp at different positions of the seed i.e. from micropylar end, distal end, pricking in middle of the seed and complete removal of endocarp to allow the free entry of water into the seed.

Extract of the endocarp (Thapliyal and Nautiyal, 1989) was obtained by grinding 3 g of the material in 50 ml of distilled water and filtering it through double layers of muslin cloth. In another set, 20 intact seeds were suspended in 50 ml of distilled water for 18 hours to obtain the endocarp leachates. Both the extract and leachate were used for irrigating the seeds put for germination in petridishes.

RESULTS AND DISCUSSION

Germinability of intact and excised seeds of neem is depicted in Fig. 1. There was a marked difference in the rate of germination and final germination percentage of seeds kept with and without endocarp. Removal of endocarp not only brought an early onset of germination but the percentage germination also improved about three times. The excised seeds germinated rapidly, radicle appeared within 24 hours accomplishing maximum germination of 95 per cent within 8 days of imbibition, whereas, in intact seeds, the rate of germination was slow and the maximum germination of 28 per cent was attained only after 30 days of imbibition.

Although the excised seeds imbibed considerable amount of water about as much as its own weight, the intact seeds imbibed only about 9 per cent of its original weight (Table 1). The water imbibed by the intact seeds was mainly confined to the endocarp since the seeds excised from intact imbibed seeds did not show any increase in their original weights. The initiation of germination was slower in seeds kept in dark when observed after 2nd and 6th day of plating (Table 2). However, by

Table 1. Water uptake in *neem* seeds with endocarp intact and without endocarp

Treatment	Weight of 10 seeds (g)	
	Before imbibition	24 hrs after imbibition
Seeds with intact endocarp	3.10 ± 0.84	3.39 (1.94)* ± 0.63 (0.02)
Seeds without endocarp	1.90 ± 0.020	3.22 ± 0.028

* Wt. of the seed after endocarp removal.

Table 2. Effect of light on the germination of *neem* seeds without endocarp

Treatment	Germination percentage*			
	Days after seed plating			
	2	6	10	12
Light	48	92	94	94
Dark	20	74	94	93

* Average value of three replicates.

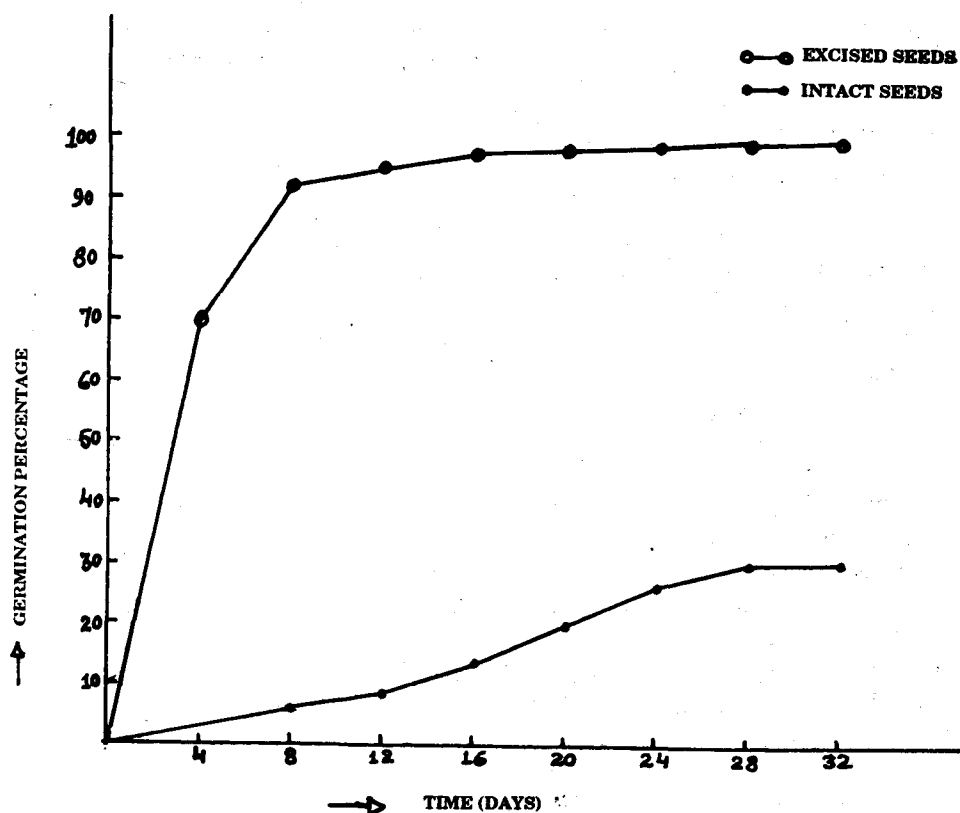


Fig. 1. Germination behaviour in *neem* seeds.

10th day, this was found to be at par with the seeds kept under light conditions. Studies on effect of scarification indicated that germination percentage (Table 3) was improved by 11 per cent in seeds pricked from lower surface, 61 per cent in seeds

Table 3. Effect of scarification of endocarp from various positions of seed on the germination percentage

Treatment	Germination percentage*	Days for germination
Intact seeds	9.0 $\pm$ 3.65	30
Endocarp pricked from the middle of seed	20.0 $\pm$ 3.53	20
Endocarp removed from micropylar end	82.0 $\pm$ 2.82	10
Endocarp removed from distal end	70.0 $\pm$ 10.6	12
Endocarp completely removed	98.0 $\pm$ 1.4	8

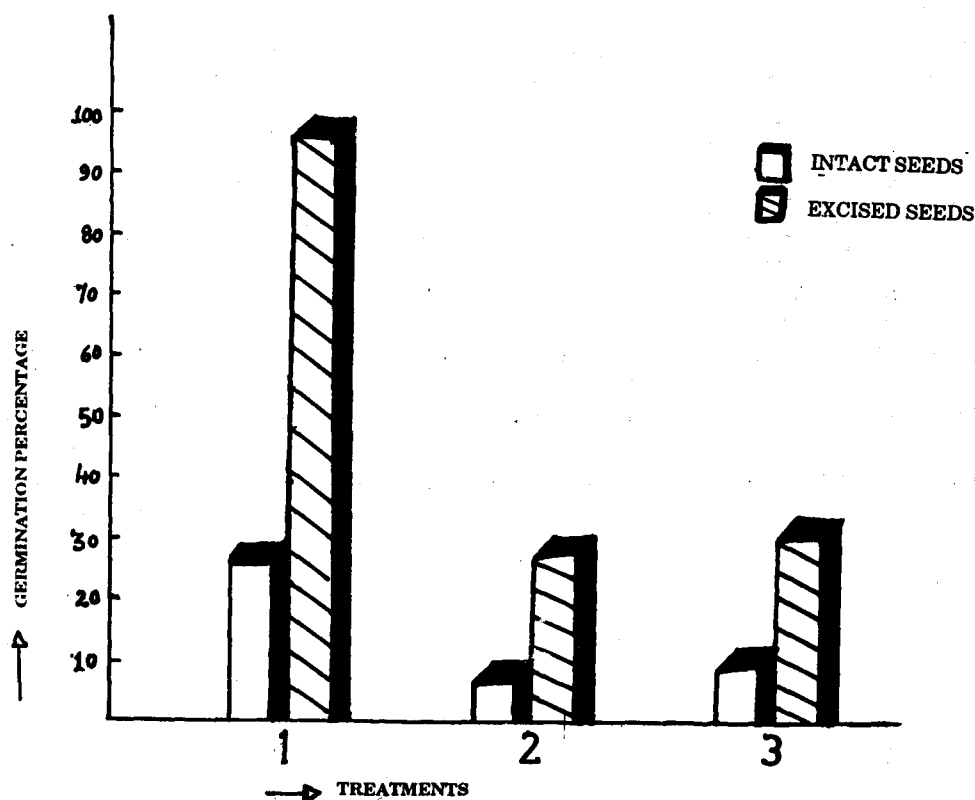
* Average value of three replicates

where the endocarp was removed from distal end of seed, 73 per cent in seeds where endocarp was removed from micropylar end and 90 per cent in seeds where the whole endocarp was removed compared to the control seeds with intact endocarp.

The results revealed that germination was not adversely affected in dark implying that endocarp did not inhibit germination in dark thereby not acting as a barrier for light penetration. However, the endocarp delayed the onset and per cent germination considerably by delaying the uptake of water (Table 3). Thus, water does not become readily available for the seeds (cotyledons) to initiate germination process. The fact that even after 32 days of imbibition, the germination percentage of intact seeds was significantly lower than that obtained with excised seeds. This suggested that the endocarp imposes mechanical resistance, to the extent that about 60 per cent of the seeds remained ungerminated. This response was mainly because of the resistance imposed on the growth of the embryo as evident from the results obtained by scarification of seeds. Although in all the scarification treatments, water was readily available to the cotyledons, the highest germination percentage was obtained where the endocarp was removed from micropylar end i.e. nearest to the embryo. Besides improving water uptake, scarification of the seeds would also improve gas exchange to take place which in turn might have improved the germination percentage in comparison to seeds sown with endocarp intact. Interestingly, seeds sown with endocarp removed from micropylar end, showed 16% lower germination percentage compared to seeds where the whole endocarp was removed. This ruled out the possibility of presence of any inhibitor (s) in the embryo alone which otherwise would have leached out slowly during imbibition in both the treatments bringing the germination percentage to the same level. Inhibition of germination by endocarp is known to be accomplished by disallowing water uptake, gas exchange, penetration of light, escape of any inhibitor(s) if present from embryo (Villiers and Wareing, 1965 and Valio, 1976), as abscissic acid is one of the prominent identified inhibitor which is not only found in covering tissue but also in embryo (Sondheimer *et al.*, 1968) or by exerting a mechanical resistance to embryo growth or by presence of any inhibitor (Bewley and Black, 1982; Valio, 1976). Since most of the factors studied could not prove fully the cause for the low germination in intact seeds, a test for the presence of an inhibitor in the endocarp was carried out.

The germination of seeds in test solutions was strongly inhibited and the values for the germination percentages (Fig. 2) were found to be as low as 27 per cent in excised seeds and 7 per cent in intact seeds with extract and leachate, respectively. This suggested presence of water soluble inhibitor in the endocarp. This inhibitor alone would have been responsible for the lower germination in seeds sown with endocarp removed from micropylar end, since under such condition neither water, gases or light were limiting nor there was any mechanical barrier imposed on the embryo when compared to excised seeds. An inhibitory extract has been reported to be isolated from embryos of *Fraxinus excelsior* (Villiers and Wareing, 1965). The reduction in the germinability of the intact seeds in the presence of endocarp extract and leachate over the control is indicative of the fact that the concentration of the

probable inhibitor present may be determining the extent of inhibition. The results revealed that inhibition in germination of neem seeds was due to the nature of thick endocarp which acted both as a mechanical barrier and also a barrier for water.



Treatment 1:

Seeds germinated on filter paper disc moistened with distilled water

Treatment 2:

Seeds germinated on filter paper disc moistened with endocarp extract

Treatment 3:

Seeds germinated on filter paper disc moistened with endocarp leachate

Fig. 2.

Germinability of intact and excised *neem* seeds in the presence and absence of endocarp extract and leachate.

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GENETIC RESOURCES AND THEIR EVALUATION IN GINGER

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Ginger (Zingiber officinale Rosc.) is believed to have originated in South-East Asia probably in India or China. It is grown in almost all the tropical countries of which China, Taiwan, Philippines, Sierra-Leone, Jamaica and Nigeria are important. India produces 1,35,000 tonnes of ginger annually from an estimated area of 53,600 hectares. Rio-de-Janeiro, China and Jamaica among the exotic group and UP, Maran, Karakkal, Ernad Chernad, Kurupamppadi, Nadia, Sleeva local, Narasapattam, Thingpuri, Vengera, Valluvanad, Mananttodi, Tura, Burdwan, Gurubathan, Tinkladium, Wynad Kunnamengulam and local types among the indigenous group, are cultivated extensively. Suprabha (PGS-35) and Suruchi (PGS-19) were released for commercial cultivation and V_K-3 is in pre release multiplication stage among the mutants. One hundred and forty accessions were collected under the auspices of All India Coordinated Spices Improvement Project, Pottangi. Out of these, 124 accessions were evaluated in a phased manner and useful accessions were identified.

Ginger (*Zingiber officinale* Rosc.) belongs to family Zingiberaceae which comprises 47 genera and about 1,400 species. The ginger has probably originated in South-East Asia (Bailey, 1949). Ginger was brought to Mediterranean region from India by traders during 1st century (Burkill, 1966) and by Arabs to East Africa during thirteenth century. It was spread to West Africa by Portuguese for commercial cultivation. Presently, ginger is grown in almost all the tropical countries like India, China, Taiwan, Philippines, Sierra Leone, Jamaica and Nigeria on commercial scale. India produces about 1,35,000 tonnes of ginger annually from an estimated area of 53,600 hectares. Kerala is the leading state in area and production of ginger followed by Orissa, Meghalaya, Himachal Pradesh, Karnataka, Mizoram, Manipur, Tamil Nadu, Maharashtra, Bihar, Tripura, Gujarat, Uttar Pradesh, Nagaland, Rajasthan, Haryana, Assam and to some extent in Jammu and Kashmir, Sikkim and Arunachal Pradesh.

The National Bureau of Plant Genetic Resources initiated all India survey of ginger germplasm in collaboration with Central Plantation Crops Research Institute, Kasaragod and Himachal Pradesh Agricultural University, Palampur during the year, 1976-77 and considerable germplasm was collected (Thomas, 1980). Gene erosion was visible because an introduced exotic cultivar Rio-de-Janeiro had replaced the local landraces/cultivars in many areas. Thus collection and conservation of ginger germplasm on priority basis was essential. In the present paper, an attempt has been made to provide useful information on evaluation and classification of ginger germplasm collected from Eastern Ghat High Land Zone of Orissa.

MATERIALS AND METHODS

The All India Coordinated Spices Improvement Project, Pottangi has collected 140 accessions from different ginger growing centres (Table 1) in collaboration with the Central Plantation Crops Research Institute, Kasaragod; National Research Centre for Spices, Calicut; Kerala Agricultural University and different State Government Departments. These have been maintained at Pottangi situated in the Eastern Ghat High Land Zone of Orissa. Eight exotic and 116 indigenous types were grown in augmented block design and evaluated systematically during 1987-90 for 21 different morphological and economic characters.

Table 1. Source of ginger germplasm

Source of Collection/Introduction	Collections
EXOTIC GERMPLASM	8
Brazil, China, Jamaica	
INDIGENOUS GERMPLASM	
Kerala, Orissa, Meghalaya, Himachal Pradesh, West Bengal, Andhra Pradesh, Madhya Pradesh, Karantaka, Mizoram, Manipur, Tamil Nadu, Maharashtra, Bihar, Tripura, Gujarat, Uttar Pradesh, Nagaland, Rajasthan, Sikkim and Assam	132
Total	140

RESULTS AND DISCUSSION

The accessions were classified according to the source of collection and categories (Table 2). The landraces were named after the place of collection. The wild ginger collected from Eastern Ghats is shown under wild taxa. Mutants were isolated by mutagenesis with gamma rays, EMS, Sodium Azide and Colchicine (Mohanty, 1984). Out of the 14 mutants, V₁K₁-3 (UP irradiated with 1 kR gamma rays) and V₂E₅-2 (Rio-de-Janeiro treated with 1.0 per cent EMS) are in the coordinated multi-localational trial and the rest are under initial evaluation trials. Among the advanced cultivars, PGS-35 and PGS-19 developed by clonal selections from *Kunduli* local were released as *Suprabha* and *Suruchi* for commercial cultivation in Orissa.

Considerable variability was observed in plant height (29.0-61.6 cm), tillers per plant (6.0-13.8), leaves per tiller (6.7-14.1), leaf length (13.5-24.5 cm) and breadth (1.2-1.9 cm) of fully opened last leaf, dry straw yield (8.4-33.0 g), fresh rhizome yield (50-250 g), number of rhizome fingers per plant (17.6-38.7), length of rhizome (8.7-17.7 cm), thickness of rhizome (1.8-3.5 cm), number of adventitious roots (3.0-7.6), tuberous roots (4.5-25.9), root yield per plant (9.4-66.7 g), dry ginger recovery (13.5-29.7%), oleoresin content (4.9-10.8%), essential oil (0.6-2.4%), crude fibre (3.4-6.4%), incidence of scale insect (0.7-3.9 score value in 0 to 5 scale), soft rot (0.96%) and leaf spot 0-7.5 index value in 'O'; nil to 5 scale) incidences. The promising accessions identified for specific traits are listed in Table 3.

Table 2. Classification of ginger germplasm

Type	Class	Accessions	Total No.
EXOTIC	Landrace	Rio-de-Janeiro, China, Jamaica	3
	Mutant	V ₂ E ₆ -8, V ₂ E ₄ -5, V ₂ S ₁ -7, V ₂ E ₅ -2, V ₂ E ₆ -3	5
INDIGENOUS	Wild taxa	Wild type	1
	Landrace	Maran, Ernad Mangeri, Turia local-2, Kotagarh, Kurupamppadi, Wynad local, Anamika, Ernad Chernad, UP, Burdwan No. 1, Burdwan No. 2, Turia local, Zaheerabad, Chintapalli local, Singh-Jhara, Taffingiva, Sargiguda, Kurmaput local, K. Local, Vengara, Tura, Narasapattam, Laxmipur local, Junagarh, Thingpuri, Tinladium, Wynad Kunnumangulam, Bhittekatta, H.P., Nadia, Karakkal, Gurubhathan, Vhaisay, Narag, Wynad Local, Rajgarh, Gendori, Nawarangpur, Kakriguma	43
	Advanced Cultivar	PGS-43, PGS-19, PGS-4, PGS-38, PGS-12, PGS-10, PGS-11, PGS-23, PGS-14, PGS-8, PGS-15, PGS-22, PGS-31, V.S., PGS-13, PGS-33, PGS-16, PGS-1, PGS-20, S-607, PGS-28, PGS-51, PGS-9, S-638, S-645, S-666, PGS-24, PGS-39, PGS-37, No. 21, No. 14, S-558, No. 15, No. 5, No. 18, PGS-17, PGS-29, PGS-26, PGS-7, PGS-44, S-62, S-641, S-557, No. 1, PGS-35, No. 20, PGS-3, S-646, No. 17, No. 8, No. 23, No. 6, No. 9, No. 19, No. 22, No. 3, Sikkim selection No. 1, SG-551, B-1, SG-212, SG-30, SG-547, SG-600, ZO-17, ZO-8, ZO-16, SO-1, ZO-18, ZO-36, ZO-14, ZO-13, ZO-2, ZO-9.	73
	Mutant	V ₁ S ₁ -8, V ₁ K ₁ -2, V ₆ E ₅ -4, V ₁ C-8, V ₁ E ₄ -5, V ₁ E ₄ -4, V ₄ E ₄ -1, V ₁ E ₉ -1, V ₁ E ₈ -2, V ₃ S ₁ -8, V ₁ S ₁ -2, V ₁ S ₁ -4, V ₁ K ₁ -3, V ₁ K ₁ -1	14
Total			140

Yield superiority of *Rio-de-Janeiro*, *Thingpuri*, *U.P.*, *Kerakkal*, *Maran*, *Suprabha* and *Jujigan* has been reported by several workers (Muralidharan and Sakunthala, 1974; Anonymous, 1978; Sreekumar *et al.*, 1980; Nybe and Nair, 1979 and Mohanty, 1984). Rhizomes of China, Taffingiva and SG-35 are bold and that of *Suruchi* and *Kunduli* local were slender (Anonymous, 1988 and Mohanty *et al.*, 1981). Further China, U.P., Nadia, Poona and Jamaica were less fibrous types (Nybe and Nair, 1979). High oleoresin content was observed in *Rio-de-Janeiro*, *Kurupamppadi*, *China*, *Ernad-Chernad*, *H.P.*, *Karakkal* and *Valluvanad* (Sreekumar *et al.*, 1980). Studies on reaction to soft rot, leaf spot and scale insect had been carried out by several workers (Mohanty, 1984;

Premanathan *et al.*, 1980 and Nybe and Nair, 1979). *Burdwan-1*, *Anamika*, *Poona*, *Maran* and *H.P.* were observed to be less susceptible to soft rot, while wild ginger, *Maran* and *Kunduli* local were less susceptible to *Phyllosticta* leaf spot as compared to other cultivars, Rhizomes were less susceptible to scale insects in wild ginger, *Anamika* and *Turia local-1*.

Table 3. Promising accessions of ginger for specific traits

Traits	Accessions
High yield	Rio-de-Janeiro, UP, Thingpuri, Karakkal, Maran, Suprabha, Jugijan
Bold rhizome	China, Taffingiya, SG-35
Slender rhizome	Suruchi, Kunduli local
High dry recovery	Turia local-2, Maran, Nadia, Karakkal, Suruchi, Tura, Thodpuzha
Less fibre content	China, UP, Nadia, Poona, Jamaica
High oleoresin content	Rio-de-Janeiro, Kurupamppadi, China, Ernad, Chernad, HP, Karakkal, Valluvanod
Less susceptibility to soft rot	Burdwan-1, Anamika, Poona, H.P.
Less susceptibility to leaf spot	Wild ginger, Maran, Kunduli Local
Less susceptibility to scale insect	Wild ginger, Anamika, Turia Local-1

The salient features of the advanced cultivars and parents and Mutants are presented in Table 4. *Suprabha* (PGS-35) and *Suruchi* (PGS-19) were developed from *Kunduli* local. *Kunduli* local has slender rhizomes with a maximum yield of (18.5 t/ha) and an average yield of 8.5 t/ha with 229 days duration. *Suprabha*, developed from *Kunduli* local, possessed unaltered maturity period with yield potential up to 22.8 t/ha. The variety has got characteristic feature of plumpy rhizome having 20.5 per cent of dry recovery; oleoresin, 8.9 per cent; essential oil, 1.9 per cent and crude fibre, 4.4 per cent. *Suruchu*, a clonal selection of *Kunduli*, recorded a maximum of 21.80 t/ha rhizome yield which is 74.4 per cent higher than its parent. *Suruchi* matures in 218 days with an average yield of 11.57 t/ha, having dry recovery of 23.5 per cent; oleoresin, 10.0 per cent and essential oil, 2.0 per cent. Both *Suprabha* and *Suruchi* have been released in Orissa for commercial cultivation. V_1K_1-3 a mutant of *U.P.* matures within 225 days and has the maximum yield potential of 24.23 t/ha with dry recovery of 23.0 per cent; oleoresin content, 10.2 per cent and essential oil, 2.1 per cent. In respect of yield, oleoresin content and essential oil, this mutant appears to have an edge over the released varieties.

Table 4. Description of parents, advanced cultivars and mutants

Cultivar	Duration (days)	Yield (t/ha)		Dry recovery (%)	Oleoresin (%)	Oil (%)	Crude fibre (%)
		Av.	Max.				
Kunduli	229	8.57	12.50	18.5	8.0	1.6	3.9
U.P.	238	9.16	14.20	20.4	7.2	1.3	4.4
Suruchi	218	11.57	21.80	23.5	10.0	2.0	3.9
Suprabha	229	16.55	22.80	20.5	8.9	1.9	4.4
V ₁ K ₁ -3	225	16.67	24.23	23.0	10.2	2.1	4.0

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**INTERSPECIFIC HYBRIDIZATION AND CROSSABILITY
STUDIES AMONG CULTIVATED AND CLOSELY RELATED
WILD *Vigna* SPECIES IN INDIAN GENE CENTRE**

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Interspecific crosses among different cultivated and wild species of genus Vigna were attempted involving mung bean (V. radiata (L) var. radiata Wilczek), V. radiata (L) var. sublobata (Roxb.) Verdc., urad bean (V. mungo (L) Hepper) and wild progenitor V. mungo (L) var. silvestris Lukoki Marechal and Otoul. The reciprocal crosses were simultaneously attempted in each cases and vice-versa. Several other crosses between V. radiata var. sublobata and V. trilobata Ait. and also with rice bean (V. umbellata (Thunb.) Ohwi and Ohashi were performed. Successful crosses were established between mung bean with its wild putative progenitor form V. radiata var. sublobata. Fertile F₁ hybrids were also successfully produced from crosses involving urad bean with its closely allied species V. mungo var. silvestris. Interestingly, mung bean when used as a female parent in the cross combinations involving var. sublobata and var. silvestris independently, exhibited considerable cross compatibility. The results clearly suggest that above allied taxa fall into the primary genepools and do not possess genetic barriers. V. umbellata exhibited cross incompatibility barriers when crossed with V. radiata var. sublobata. The reasons for failure of crosses have been critically analysed deriving evidential support from several other investigations. The paper presents a comprehensive review on the interspecific hybridization to identify closely related genepools of Asiatic species of Vigna based on crossability studies.

Interspecific hybridization has played significantly important role in the speciation and evolution of several flowering plants in nature. At the sometimes, experimental hybridization has been used to study the nature and extent of isolating barriers operating between species, such studies also provide evidences for understanding the phylogenetic relationships (Ahn and Hartmann, 1978). Further interspecific crosses among cultivated and wild progenitors and weedy races are important for the understanding of the extent of crossability in order to ascertain the success of gene transfer from wild to the advance cultivars. It is well recognised fact that weedy races have served as reservoirs of germplasm periodically transferring/exchanging genes into the crop under conditions that would most favour increase in variability, heterozygosity and heterosis (Harlan, 1975). Weedy races have played immensely valuable role in the evolution of domesticated plants.

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However, once isolated from cultivated forms have no mechanism to transfer genes even occasionally unless helped by man under controlled environments. Similar situation exists among genus *Vigna* sub section 'Ceratotropies', where wild occurring closely related species possess useful genes, that could easily be transferred from them to the cultivated species, once our knowledge about their relationships and mechanism for the exchange of genes is well understood. Unfortunately there has been regrettable lack of consistency among taxonomists in naming such species and forms, the expedient of naming them as subspecies has created considerable confusion (Smartt, 1979; 1990). The *Vigna* species group provides such an example. Infact this problem could be avoided by adoption of a constant practice in the naming of conspecific wild and cultivated forms. This perhaps could be most helpful in further investigations. The present study is an attempt to highlight the results of the interspecific hybridization and crossability studies among *mung*, *urad*, rice bean and their well authenticated wild putative progenitor species/forms.

MATERIALS AND METHODS

Interspecific hybridization and crossability studies were attempted between *mung* bean (*Vigna radiata* (L) Wilczek) and its wild progenitor species *V. radiata* var. *sublobata* Verdc.; also between *urad* bean (*V. mungo* (L) Hepper) and its wild progenitor species *V. mungo* var. *silvestris* Lukoki Marechal and Otoul. Reciprocal crosses among above species were also attempted. Besides, interspecific crosses were made between *V. trilobata* and *V. umbellata* independently with *V. radiata* var. *sublobata* Verdc. For above mentioned species crosses, two accessions each in *mung* bean (Plm 586 and Plm 124), *V. radiata* var. *sublobata* (Plx 270 and Plx 274), *urad* bean (Plu 261 and Plu 274) and four accessions of wild *V. mungo* (L) var. *silvestris* (Plx 298, Plx 409, Plx 413 and Plx 416) were utilized. Besides, one accession each in *V. umbellata* and *V. trilobata* was involved in the cross with *V. radiata* var. *sublobata*. The material was grown in the field at NBPGR farm at Pusa Campus, New Delhi. Each accession was planted in two rows, each 2 m long, 60 cm apart with 15 cm distance between plants. Interculture operations and prophylactic measures were adequately adapted to grow a good healthy crop. To avoid any risk, different species were also grown in pot culture under controlled green house conditions. The emasculation was carried out during the month of September between 3 to 5 PM and pollination was carried out next morning between 8 to 9 AM. The details of the material, main distinguishing features of each species and details of crosses etc., are given in Table 1 and Table 2, respectively. Approximately 250 crosses were attempted in all combinations among six cultivated and wild *Vigna* species.

RESULTS AND DISCUSSION

Among the 250 crosses attempted between cultivated species of *mung* bean, *urad* bean and their wild ancestral forms *V. radiata* var. *sublobata* and *V. mungo* var. *silvestris* respectively, involving several accessions resulted in variable success. The crosses between *V. umbellata* and *V. radiata* var. *sublobata* and between *V. trilobata* success showed only in latter case.

Table 1. Major differences between important cultivated and allied wild *Vigna* species

S. No.	Characters	Mung bean (<i>V. radiata</i>)	Wild Progenitor (<i>V. radiata</i> var. <i>sublobata</i>)	Urad bean (<i>V. mungo</i>)	Wild progenitor (<i>V. mungo</i> var. <i>silvestris</i>)	Moth bean (<i>V. aconitifolia</i>)	Rice bean (<i>V. umbellata</i>)	<i>V. trilobata</i>
1.	Distribution/ Occurrence	Widely cultivated in India	Natural habitats, widely spread in Himalayas, North- ern plains and peninsular India	Widely cultivated in India	Wild, natural, Disturbed habitats in Poona-Khandla region, Western Ghats	Widely cultivated North-Eastern India, central India and Decan Plateau	Mainly cultivated North-Eastern India Sikkim, W. Bengal, Bihar and Orissa	Semi wild, wide spread in northern plains, central India
2.	Plant type growth habit	Dwarf, erect, deter- minate, branched, vigorous	Erect indeterminate, long internodes vig- orous branched	Dwarf, erect, semi prostrate to inde- minate type, viny	Thin stemmed tendrillous forms. condensed inter- form exist	Erect viny, semi prostrate to procum- bent forma, branched node, branched	Erect to viny inde- terminate forms profusely branched	Erect to semi- viny cultigen forms Vigour- ous forms diffused
3.	(a) Leaflet shape	Entire, broad	Small, elongated	Variable shape	Small to modera- tely large	Small moderately lobed to highly dissected	Large, broad moderately lobed	Small, deeply lobed
	(b) Post cotyl- edonary leaf	Sessile	Sessile	Sessile	Sessile	Petiolate	Petiolate	Petiolate
4.	Seedling pigmentation	Green	Green	Purplish	Purple	Purple	Purple	Nonpigmented
5.	Stipule (shape/ size)	Broad, peltate	Broad peltate	Linear lanceolate	Linear lanceolate	Moderately broad	Broad lanceolate	Small peltate
6.	Pod size (cm.)	4.0 - 16.0	4.0 - 6.0	4.0 - 8.0	2.8 - 4.2	3.0 - 4.5	7.5 - 14.0	2.5 - 4.5
7.	Pod shape	Straight, sickle shaped, cuneate	Straight, slightly cuneate	Slightly curved, cuneate	Slightly curved cuneate	Small, slightly curved, cuneate	Pod straight or curved, cylinde- rical	Small, straight or slightly curved
8.	Pod colour	Brown, dark tan	Black, straw coloured	Brown, tan	Straw coloured	Straw coloured, brown	Brown or straw coloured	Brown or straw coloured
9.	Pods/peduncle	4 - 8	4 - 8 Sometimes only 1	4 - 8	4 - 6 Generally in cluster	3 - 5	3 - 11	2 - 6,
10.	Orientation of pods on peduncle	Ascending suberect	Ascending suberect	Usually borne hori- zantly or facing upward	Usually borne hor- izontally deflexed type	Ascending	Ascending suberect, drooping	Usually asce- nding, borne horizontally
11.	Pod dehiscence	Delayed shattering	Violent shattering	Delayed shattering	Violent shattering	Delayed shattering in cutigen and vio- lent in wild forms	Delayed shatter- ing in cultigen and violent in wild forms	Highly violent shattering

	Peduncle size	Small to moderately long	Moderately long	Long	Moderate	Moderate	Very long
12.	Peduncle size	Small to moderately long	Moderately long	Long	Moderate	Moderate	Very long
13.	Pubescence	Smooth or mildly hairy	Hairy plant type, pods pubescent	Hairy pods	Plants non hairy, pods mildly hairy	Pod glabrous	Glabrescent leaves and pods
14.	Seeds/pod	8 - 16	8 - 14	10 - 14	6 - 8	8 - 12	8 - 12
15.	Seed colour (S)	Yellow, green brown and chocolate	Dark brown, tan	Dark brown, tan	Green, greyish	Yellow, green, red, brown, black, chocolate (very variable)	Brown, blackish
16.	SEM seed coat cellular structure	Elongated, rectangular cells arranged in parallel rows	Very much elongated, rectangular cells arranged in parallel rows; similar to cultigen	Moderate hexagonal cells, cup shaped, similar to cultigen	Epidermal cells irregular	Seed surface smooth epidermal cells arranged in network	Epidermal cells hexagonal, cup shaped
17.	Hilum shape and structure	Linear, flatish not raised	Linear, flatish not raised	Deeply furrowed, concave raised and arilate	Linear, wedge shaped arilate	Prominent, raised rectangular hilum, broad in shape set on one side	Semi raised hilum, broad
18.	Seed germination habit	Epigeal	Epigeal	Epigeal	Epigeal	Hypogeal	Epigeal
19.	Protein (%)	20.4 - 26.90 (23.6)	15.7 - 22.0	26.00	22.5	19.0 - 25.0 (25.0)	14.8 - 18.5
20.	Average (%) C DNA content (pg.)	2.67	*	*	*	2.84	2.60
21.	Y-glytaml met-hionine and its sulfoxide	Absent	Absent	Present	*	*	*
22.	Y-glutamyl-S methyle Cystine and its sulfoxide	Present	Present	Absent	*	*	*
23.	Presences/absence Amino acids	Methionine (1.14)	Methionine (1.18)	Methionine (2.00)	*	Methionine (1.18)	*

* Information not available

Cross I. *V. radiata* x *V. radiata* var. *sublobata*.

The above cross was fully compatible. The two accessions of *mung* bean (Plm 586 and Plm 124) crossed freely with var. *sublobata* (Plx 274). The fertile hybrids were obtained in above cross. The initiation of pod set among pollinated buds took place in 64 per cent cases, while 48 per cent pods reached the full maturity stage with well developed pods/seeds. The harvested seeds possessed 100 per cent viability. The pollen fertility of F_1 hybrid was as high as 90 per cent. The other strain of *mung* bean (Plm 124) crossed very well with var. *sublobata* (Plx 274) and in both the crosses, hybrids were fully fertile and vigorous, being twiny. Leaves were like *V. radiata* while pods and seeds resembled more like *V. radiata* var. *sublobata*. However, cross involving *mung* bean with wild var. *sublobata* (Plx 270) was unsuccessful. The cross combination of *mung* bean, *urad* bean and their wild forms exhibited pod initiation only in 16 per cent cases, out of which only 40 per cent reached maturity.

Cross II. *V. radiata* var. *sublobata* x *V. radiata* (Reciprocal cross).

In the reciprocal cross involving var. *sublobata*, the wild progenitor forms (Plx 274 and Plx 270) as female parent and cultivated *mung* bean (Plm 586), 24 per cent pods were initiated, 22 per cent reached maturity while remaining 78 per cent pods dropped after 6-10 days of initiation. Four seeds obtained from this cross were shrivelled and did not germinate.

Cross III. *V. radiata* x *V. mungo* var. *silvestris*

Mung bean accession Plm 586 was crossed with var. *silvestris* (Plx 409, Plx 298 and Plm 416). Out of buds emasculated, 23 per cent pods initiated but only 11 per cent reached maturity yielding 4 shrivelled seeds. Remaining buds dropped after 8-11 days of initiation.

Cross IV. *V. mungo* var. *silvestris* x *V. radiata* (Reciprocal cross).

Pollination of var. *silvestris* using four wild type accessions (Plx 298, Plx 409, Plx 413 and Plx 416) did not result in pod initiation due to cross incompatibility. It clearly indicated that perhaps some genetic barriers existed between these wild putative ancestral forms of *urad* and *mung* bean.

Cross V. *V. mungo* x *V. mungo* var. *silvestris*

Two well identified and authenticated *urad* bean accessions (Plu 261 and Plu 274) were crossed with var. *silvestris* (Plx 298 and Plx 409) as pollen parent.

(i) *V. mungo* (Plu 274) x *V. mungo* var. *silvestris* (Plx 298)

(ii) *V. mungo* (Plu 261) x *V. mungo* var. *silvestris* (Plx 409)

The crosses were fully compatible and fertile F_1 hybrids were successfully established showing that post zygotic isolating mechanisms were not operative between these two species and there is free exchange of genes. The hybrids were more vigorous and early flowering than both the parents. Plants were viny with narrow lanceolate leaves like that of var. *silvestris* while pods and flower colour resembled like *urad* bean.

Cross VI. *V. mungo* var. *silvestris* x *V. mungo* (Reciprocal).

In this reciprocal cross, 18 per cent pods were initiated, but only about 25 per cent of these reached maturity. Matured pods yielded few shrivelled unfilled seeds which did not germinate possibly due to embryo inviability.

Cross VII. *V. mungo* x *V. radiata* var. *sublobata*.

This cross was not attempted earlier due to taxonomic and nomenclatural confusion that existed before. The F_1 hybrid from the cross (Plu 261 x Plx 270) was more like female parent in plant habit, leaf shape and branching pattern. It possessed small pale yellow flowers and very short, condensed internodes. The pollen was highly sterile (upto 74%); bud initiation took place but no seed setting was observed. The crossability results showed that cross incompatibility exists between *urad* bean (*V. mungo*) and wild progenitor from *V. radiata* var. *sublobata*.

Cross VIII. *V. radiata* var. *sublobata* x *V. mungo*. (Reciprocal).

When var. *sublobata* buds were pollinated from pollen obtained from cultivated accessions of *urad* bean, 3 per cent pod initiation took place but none of the pods reached maturity.

Cross IX. *V. radiata* var. *sublobata* x *V. mungo* var. *silvestris*.

The above cross involved both the wild putative progenitor forms of *mung* and *urad* beans respectively. Two wild accessions of var. *sublobata*, Plx 270 (Chandigarh) and Plx 274 (Rishikesh) were crossed as female parents with var. *silvestris* (Plx 409, Plx 298 and Plx 416) as pollen parent. Among this group, pod initiation was observed only in the cross Plx 270 x Plx 409. 18 pollinations were attempted, out of which in 33 per cent cases, pods were initiated, while only 5-8 per cent pods attained maturity and five seeds were obtained giving rise to sterile hybrids. The F_1 hybrid possessed intermediate stipules of moderate width, the flower colour and leaves were similar to that of var. *sublobata*. Interesting results were obtained in the reciprocal crosses involving var. *silvestris* x var. *sublobata*. The var. *silvestris* (Plx 409 and Plx 298) were crossed with var. *sublobata* (Plx 270 and Plx 274). Out of 28 buds pollinated, 23 pods initiated and 23 per cent pods matured yielding to fully ripened seeds. The F_1 hybrids had twiny plant habit, intermediate plant type and flower colour and were observed to be sterile.

Cross X. *V. mungo* var. *silvestris* x *V. radiata* var. *sublobata* (Reciprocal).

In this unique reciprocal cross between two wild putative progenitor forms of *urad* and *mung* beans respectively four distinct forms were hybridized as female parent with two distinct forms of var. *sublobata* as pollen parent Table 2. The pod initiation was not observed in most of the crosses except in a cross involving Plx 409 x Plx 274. In this cross, pollen fertility was found to be very low resulting in complete sterility.

Cross XI. *V. radiata* var. *sublobata* x *V. trilobata*

The cross between wild putative progenitor of *mung* bean (*V. radiata* var. *sublobata*) with the wild occurring types *V. trilobata* was very interesting. In this

Table 2. Interspecific crosses among cultivated and wild Asiatic *Vigna* species in India

Cross	Buds pollinated	Pods initiated	No. of days after pods dropped	No. of pods matured	No. of seeds obtained	Germination %	(F1 (Hybrids))	
							Pollen Fertility %	Pod setting
I <i>V. radiata</i> x <i>V. radiata</i> var. <i>sublobata</i>								
Plm 586 x Plx 274	25	16	2 pods dropped in 12 days	12	28	100	90%	Fertile
Plm 586 x Plx 270	14	0	1 " " " 8 "	0	-	-	-	-
Plm 124 x Plx 274	16	4	1 " " " 4 "	2	2	100	80-90	Fertile
Plm 124 x Plx 270	2	-	1 " " " 4 "	-	-	-	-	-
Plm 1290 x Plx 274	10	2	2	7	100	90	-	Fertile
II <i>V. radiata</i> var. <i>sublobata</i> x <i>V. radiata</i> (Reciprocal)								
Plx 270 x Plm 586	22	3	2 pods dropped in 8 days	-	-	-	-	-
			1 " " " 6 days					
Plx 274 x Plm 586	20	6	2 " " " 10 days	2	4	0	-	-
			2 " " " 8 days					
Plx 270 x Plm 124	10	-	-	-	-	-	-	-
Plx 274 x Plm 124	10	-	-	-	-	-	-	-
III <i>V. radiata</i> x <i>V. mungo</i> var. <i>silvestris</i>								
Plm 586 x Plx 409	28	6	1 pod dropped in 10 days	1	4 shrivelled seeds	0	-	-
			3 " " " 8 days					
			1 " " " 7 days					
Plm 586 x Plx 298	6	2	2 " " " 11 days	-	-	-	-	-
Plm 586 x Plx 416	5	2	1 " " " 9 days	-	-	-	-	-
IV <i>V. mungo</i> var. <i>silvestris</i> x <i>V. radiata</i>								
Plx 298 x Plm 586	15	-	-	-	-	-	-	-
Plx 238 x Plm 124	10	-	-	-	-	-	-	-
Plx 409 x Plm 586	12	-	-	-	-	-	-	-
Plx 413 x Plm 586	8	-	-	-	-	-	-	-
Plx 413 x Plm 124	8	-	-	-	-	-	-	-
Plx 416 x Plm 586	18	-	-	-	-	-	-	-
Plx 416 x Plm 124	16	-	-	-	-	-	-	-

(Table Continued)

(Continued from Page 52)

<i>V. mungo</i> x <i>V. mungo</i> var. <i>sibvestris</i>									
Plu 261 x Plx 298	20	2	-	-	2	6	66	90-95	Fertile
Plu 268 x Plx 409	18	2	-	-	2	4	100	90	Fertile
Plu 274 x Plx 298	16	4	-	-	4	12	100	90	Fertile
VI. <i>V. mungo</i> var. <i>sibvestris</i> x <i>V. mungo</i> (Reciprocal)									
Plx 298 x Plu 274	15	2	2 dropped in 6 days	-	-	-	-	-	-
Plx 298 x Plu 261	6	4	3 " " 9 "	-	1	2 shrivelled seeds	0	-	-
Plx 409 x Plu 261	10	-	-	-	-	-	-	0	-
VII. <i>V. mungo</i> x <i>V. radiata</i> var. <i>sublobata</i>									
Plu 261 x Plx 270	20	2	1 dropped in 12 days	-	1	2	50	50-60	Sterile
Plu 261 x Plx 274	8	-	-	-	-	-	-	-	-
Plu 274 x Plx 270	8	1	1 dropped in 7 days	-	-	-	-	-	-
Plu 274 x Plx 274	10	-	-	-	-	-	-	-	-
VIII. <i>V. radiata</i> var. <i>sublobata</i> x <i>V. mungo</i> (Reciprocal)									
Plx 270 x Plu 261	15	2	2 dropped in 10 days	-	-	-	-	-	-
Plx 274 x Plu 261	20	-	-	-	-	-	-	-	-
Plx 274 x Plu 274	15	-	-	-	-	-	-	-	-
IX. <i>V. radiata</i> var. <i>sublobata</i> x <i>V. mungo</i> var. <i>sibvestris</i>									
Plx 270 x Plx 409	20	6	1 dropped in 13 days	3	2 bold + 3 shrivelled seeds	50	-	40	Sterile
			" " " 14 days						
			" " " 15 days						
Plx 270 x Plx 298	13	-	-	-	-	-	-	-	-
Plx 270 x Plx 416	10	-	-	-	-	-	-	-	-
Plx 274 x Plx 409	14	-	-	-	-	-	-	-	-
Plx 274 x Plx 298	13	-	-	-	-	-	-	-	-
X. <i>V. mungo</i> var. <i>sibvestris</i> x <i>V. radiata</i> var. <i>sublobata</i> (Reciprocal)									
Plx 409 x Plx 270	15	-	-	-	-	-	-	-	-
Plx 409 x Plx 274	15	4	-	-	4	5 bold seeds	28	30-40%	Sterile
			-	-	-	2 shrivelled seeds	-	-	-
Plx 298 x Plx 270	13	-	-	-	-	-	-	-	-
Plx 298 x Plx 274	12	-	-	-	-	-	-	-	-
XI. <i>V. radiata</i> var. <i>sublobata</i> x <i>V. Trilobata</i>									
Plx 274 x I.W. 2488	42	5	-	28	10	-	95	-	-
XII. <i>V. umbellata</i> x <i>V. radiata</i> var. <i>sublobata</i>									
Plx 274 x I.C. 17656	39	5	-	2	2 shrivelled seeds	-	-	-	-

cross, out of the 42 buds pollinated after emasculation, only in 12 per cent cases pod initiation was observed. Out of this 69 per cent pods matured yielding 10 well developed seeds. The cross was unique in the sense that both the wild species occur sympatrically in the natural/disturbed habitats and such situation can possibly allow introgression of genes from these two or more allied species. The success of the cross resulting in the well developed hybrid seeds, suggests that these wild species constitute the same genepool. This cross has not been attempted earlier.

Cross XII. *V. umbellata* x *V. radiata* var. *sublobata*.

In all, 39 buds were emasculated and pollinated, 15 per cent pods initiated, however, only 5 per cent pods matured resulting in shrivelled immature seeds. In reciprocal cross, 28 per cent pods were initiated without yielding any mature seeds. This showed that cross was incompatible and cross ability barriers existed between above species. Also that var. *sublobata* is not related to *V. umbellata*. The later appears to have evolved independently from its wild occurring putative ancestral forms.

The cytological studies of the F_1 hybrids of the crosses, *Vigna radiata* x *V. radiata* var. *sublobata*; *Vigna radiata* var. *sublobata* x *V. mungo* var. *silvestris*; *Vigna mungo* x *V. mungo* var. *silvestris*; *Vigna mungo* x *V. radiata* var. *sublobata* were performed. The studies included pachytene and diakinesis analysis.

In the first cross, out of the five seeds obtained, all germinated very well. However, only 3 hybrid plants survived till maturity. The F_1 hybrid resembled female parent in plant habit, leaf shape, size and flower size, while pod and seed characters resembled with pollen parent (var. *sublobata*). The hybrids from above crosses showed 80-90 per cent pollen fertility and fertile pods were obtained. The pachytene and diakinesis showed complete pairing with eleven normal bivalents. The perfect chromosome pairing between *V. radiata* with *V. radiata* var. *sublobata* clearly suggested their close affinity and phylogentic relationships.

The flowering buds of the F_1 hybrids between a cross involving urad bean (*V. mungo* (L) Hepper) x *V. mungo* var. *silvestris* Lukoki, Marechal and Otoul were fixed in acetic alcohol and the meiotic studies were undertaken. In two respective hybrids produced from two independent cross combinations, the pollen fertility ranged from 80-90 per cent and 95-98 per cent respectively. The pachytene showed perfect chromosomal homology and complete pairing with eleven bivalents. Diakinesis confirmed association of 11 pairs of chromosomes. However, majority of cells showed some kind of loose association near nucleoli in 4-5 bivalents. The F_2 populations were raised through the seeds obtained from F_1 raised plants. The segregating populations (H 67, H 68, H 69, H 70, H 71, H 72 and H 73) exhibited considerable variations giving rise to very valuable recombinations for yield components, seed size, colour and resistance/tolerance to yellow mosaic virus disease.

The hybrid (*V. mungo* x *V. radiata* var. *sublobata*) was sterile with 50% average pollen fertility. The cytology of the meiosis showed incomplete pairing between all the eleven bivalents, showing loops in pachytene and 2-4 univalents in many cells at diakinesis. A tetravalent was also observed in one cell. In the cross involving two

wild putative progenitors var. *sublobata* and var. *silvestris* of *mung* and *urad* beans respectively, the hybrids were highly sterile. The pollen fertility was low and ranged between 30-40 per cent. Meiotic studies showed loops and incomplete pairing at diakinesis. Very few cells showed 11 bivalents. Most of the cells possessed 2-5 univalents.

Interspecific hybridization among several cultivated species of *Vigna* have been attempted earlier by several workers in the past two decades. However, the real situation remained hazy and blurred due to the confused nomenclature of the Indian cultigens and taxonomy of several wild occurring species and their forms continued to be eluding the correct scientific status. This fact is amply reinforced by the excellent review on interspecific hybridization (Smartt, 1979 and 1990). It was emphasized that considerable difficulty is encountered while discussing interspecific hybridization due to lack of satisfactory definition of the species. No experimental studies were reported of hybridization with wild species earlier (Smartt, 1971). This study reports the results of interspecific hybridization and crossability studies between well known cultivated species/forms and several well identified and authenticated wild species (putative progenitor forms) occurring in the natural and disturbed habitats in Indian Gene Centre.

A very comprehensive crossing programme involving 250 crosses was attempted between different species of cultivated and wild *Vigna* species comprising several accessions. The crosses between *V. radiata* x *V. radiata* var. *sublobata* was successful while reciprocal cross did not succeed. The cross involving *V. radiata* with *V. mungo* var. *silvestris* also did not yield fruitful result. Similarly, cross between two wild putative progenitor forms var. *sublobata* and var. *silvestris* resulted in sterile hybrids. The two cross combinations involving *V. mungo* var. *silvestris* as male parent and *V. mungo* as female parent, were fully compatible and fertile F_1 hybrids giving rise to useful recombinants were established. The cross established the close relationships between two species. However, reciprocal cross did not result, as matured pods yielded few shrivelled unfilled seeds which did not germinate. The cytological studies involving the meiotic homology and segregation behaviours showed perfect pairing and complete homology forming 11 bivalents at pachytene and diakinesis.

Apart from our own studies, interspecific crosses between *V. mungo* and *V. mungo* var. *silvestris* were made (Dwivedi and Singh, 1985 a). The cross was found fully compatible and F_1 , F_2 and F_3 generations were produced. The recombinants possessing resistance to *mung* bean yellow mosaic virus were recovered. The resistance was reported to be digenic and controlled by recessive genes. The hybrid between *V. mungo* x *V. radiata* var. *sublobata* and cross involving *V. radiata* var. *radiata* x var. *silvestris* gave rise to sterile hybrids showing incomplete pairing between the chromosomal complements of the species involved in the crosses. The pollen fertility being very low and formation of loops at diakinesis. The hybrid break down resulted from the embryo inviability and non homology or lack of complete pairing or due to irregular meiosis. Sterile hybrids were earlier reported in cross involving *V. radiata* x *V. mungo* (Dana, 1966). In above cross, meiosis was observed to be irregular in the hybrids and 11 bivalents were noted in 50 per cent of the cells. Similarly wild var. *sublobata* crossed very well with *V. radiata* and fertile hybrids

V. mungo, produced only shrivelled seeds (Dana, 1975). In earlier reports, the production of hybrid between *V. radiata* x *V. mungo* was reported (Sen and Ghosh, 1960). Cytogenetic differentiation apparently appeared to have occurred between the two cultigen species *mung* and *urad* beans (De and Krishnan, 1966). The above authors had based their conclusions on the assumption that *P. sublobatus* (*V. radiata* var. *sublobata* Verdc.) was the common ancestral form of both the domesticated species (de Candolle, 1886; Baker, 1879; Prain, 1897; Vavilov, 1951; Zeven and Zhukovskij, 1975), which has been disproved recently (Lukoki *et al.*, 1980; Chandel, 1984; Chandel *et al.*, 1984).

In a similar studies involving interspecific crosses, one of our wild forms of *Vigna radiata* var. *sublobata* (Plx 270,) was crossed independently with *mung* and *urad* beans (Biswas and Dana, 1945). It was reported that all the three species and their hybrids possessed $2n = 22$ chromosomes. Cytogenetic evidences of closeness of *V. radiata* var. *sublobata* with *V. radiata* was also provided (Karmakar and Dana, 1987). The hybrids of *V. radiata* x *V. radiata* var. *sublobata* possessed 78 to 90 per cent fertile pollen and produced many well developed seeds. Completely paired eleven bivalents at pachytene and equal separation of chromosomes in most of the cells at later stages in the hybrid showed that cross was fully compatible and var. *sublobata* is the close progenitor of *mung* bean. However, when Plx 270 was crossed with *V. mungo*, it exhibited 26-88 per cent pollen fertility resulting only in two shrivelled seeds. Closely paired bivalents were noted in most of the pachytene cells in F_1 hybrid. Duplication and deficiency loops were observed in few cases.

Interspecific hybridization between four cultigen species were also reported (Ahn and Hartmann, 1975; 1978). *V. radiata* produced fertile hybrids as a female parent with *urad* bean (*V. mungo*), rice bean (*V. umbellata*) and adzuki bean (*V. angularis*). However, reciprocal crosses were reported to be non-viable. A hybrid between *V. umbellata* x *V. angularis* was also reported. The meiotic studies of F_1 hybrid suggested occurrence of chromosomal structural differences between *V. radiata* and other species. In the above interspecific hybridization studies, after pod initiation in most of the crosses, embryo aborted before reaching maturity stage except in case of pollination of *mung* bean by *urad* bean and rice bean, the embryo abortion was not evident. As is the case in the present investigations, embryo culture was followed by loss of all seedlings in the seedling stage, while seedlings which survived remained weak and those which grew well produced hybrid plants with complete or partial sterility. The results indicate similar patterns in the unsuccessful crosses.

The differential behaviour of varieties/genotypes in interspecific hybridization and crossability studies emphasized clearly the need for involving more than one genotypes. Further, it may be seen from the results that reciprocal differences do exist in such interspecific crosses, the manifestation of which can be noted from embryo abortion, embryo invigorousity and seedling mortality. In this only few reciprocal crosses were successful. It is primarily due to the fact that unidirectional success is a common phenomenon in all crosses between any two species. It is believed that cytoplasmic differentiation is assumed to have played the primary role in speciation of several *Vigna* species.

In this study, a unique interspecific cross was attempted between *V. radiata* var. *sublobata* x *V. trilobata*. The cross was quite successful as out of the 42 buds pollinated, 10 well developed seeds were obtained. It suggests that gene exchange can occur between these two wild species in the nature and *V. trilobata* together with var. *sublobata* and *V. radiata* constitute the secondary gene pool. However, when *V. umbellata* was crossed as female parent with var. *sublobata* as pollen parent, the cross was not successful. Incompatibility and crossability barrier resulted in the embryo abortion and inviability. Possibly *V. umbellata* has evolved independently. Earlier, crosses between *V. radiata* x *V. umbellata* (Dana, 1966 b), with *V. trilobata* (Dana, 1966 c) and also between *V. radiata* x *V. mungo* (Dana, 1966 d) were made. Successful hybridization between *V. angularis* x *V. radiata* and *V. radiata* x *V. umbellata* were reported (Megumi Sawa, 1974). It was suggested that differentiation among *V. radiata* and *V. mungo* was less apparent (Ahn and Hartmann, 1978). According to them, some gene exchange appears to be possible between *V. radiata* and *V. mungo* and also between *V. umbellata* and *V. angularis*. However, the later species represented a closed genepools as *V. radiata* produced sterile hybrids between both the above species. The fertilization barriers were encountered in crosses involving *V. minima* and *V. umbellata*. The delay and absence of divisions in the endosperm and the failure of embryo to divide were considered as the post fertilization barriers responsible for somatoplastic sterility in normal crosses which yielded a few hybrid seeds. *V. minima* was considered to constitute genepool of the rice bean.

It has been observed in the present investigations that when closely related wild and cultivated species/forms were crossed, the hybrids produced were frequently viable and fertile in F_1 and subsequent generations such as crosses of mung bean with var. *sublobata* and that of urad bean with var. *silvestris*. It provides clear evidence that two forms (wild and cultivated) are conspecific, although much nomenclatural and taxonomic confusion has continued to prevail; and due to which such forms have been assigned different specific names. The success of presumed interspecific hybridization frequently prompts a re-examination of the taxonomic status of the hybridizing parents, where these forms produce hybrids with little or no immediate reduction of fertility and follow normal patterns of segregation. In case of genus *Vigna*, this has been a frequent case, when such forms have been confused for correct taxonomic status.

In such cases, one parent is an highly evolved domesticated species (*mung*, *urad*, *moth* or rice bean) and the other is a wild plant. There is a strong presumption that both are descendent from a common ancestral form, part of which was then domesticated, thus they are conspecific (Smartt, 1979). It is reasoned that very nature of the evolutionary mechanism, the generation of morphological and other variations of discontinuous nature between populations which enables the recognition of species/subspecies is a continuing process. It is argued (Smartt, 1979) that theoretically, a population having reached the stage of effective isolation, would then proceed to generate internally further discontinuities, if appropriate selection pressure is able to operate. Another, confusing factor in the situation arises from differences in taxonomic practice in the naming of conspecific wild and cultivated forms.

The interspecific hybridization and crossability studies among genus *Vigna* involving (i) only cultivated species; (ii) where one parent is cultivated and another is wild and (iii) where both the parents are wild has brought out the facts that failure of interspecific hybrids among *Vigna* could be attributed to several events and processes. In those crosses where hybrid was completely pollen sterile, the cytological causes underlying sterility in the hybrid encompasses array of meiotic abnormalities ranging from no pairing, presence of univalents, chain and ring multivalents and sometime anaphase bridges to the formation of micronuclei during microsporogenesis. Several earlier reports as well as present investigations amply suggest that failure to establish F_1 hybrid could occur due to failure of foreign pollen to germinate on female stigma, pollen tubes may fail to penetrate the style tissue, pollen nuclei may fail to effect the double fertilization. Often it is observed that fertilized egg or zygote may fail to develop and subsequently may abort. In some cases, endosperm may fail to develop and induce abortion of a potentially viable embryo. In some cases suspensor fail to function normally and produce a late abortion (Ahn and Hartmann, 1978). Apparently, normal seed may develop, as is the case in the several interspecific crosses in the present study, but later fail to germinate or produce a viable mature plant. Further, even if established, generally fail to reproduce sexually. If reproduction occurs poorly, viable segregants may not be able to produce offspring. Also in the segregation populations, progeny breakdown can occur (Chawdhary and Chawdhary, 1977).

Chromosomal aberrations in such interspecific crosses, as evident from occurrence of duplication, deficiency and inversions may occur resulting in disruption of normal process of sexual cycle (Dana, 1966 a, b, c). The presence of chain and ring multivalents at diakinesis not only confirms the structural hybridity of the F_1 hybrid, but also suggests that small interchanges and inversions played a significant role in the speciation within the genus *Vigna* (Gopinathan and Babu, 1986). It is also considered that reduction in fertility in all cases of interspecific hybridization provides useful confirmation of authenticity of a successful cross. It is well accepted that a low level of failure in emasculation technique is probably inevitable as indicated by above researchers. In this context, a valuable list of genetic markers for use in authentication of the interspecific hybrids between *V. radiata* x *V. umbellata* is important (Chen *et al.*, 1978). The authenticated specimens and the critical analysis of the data will eventually prove beneficial to the evolutionists, cytogeneticist and the plant breeders particularly interested in genus *Vigna*.

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METROGLYPH ANALYSIS OF DIVERSITY IN SOME QUALITY COMPONENTS IN RAINFED RICE (*Oryza sativa* L.)

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One hundred and six indigenous cultivars (mainly from plateau region of Bihar) of Oryza sativa L. were evaluated to study the extent of variation in physico-chemical and cooking quality traits. The study revealed high variability for alkali digestion value and head rice recovery; moderate for grain shape and water uptake. About 50 per cent cultivars possessed short, bold and red kernels. Sixteen genotypes exhibited desirable combination of intermediate content of amylose and gelatinization temperature. Twenty five per cent cultivars also exhibited high water uptake (more than 300 ml). Metroglyph analysis indicated that 106 genotypes could be grouped into six complexes; the largest being I and II with 29 and 24 genotypes respectively. The cumulative index score (IS) varied from 6 (Bagri Black HRC 446) to 12 (Brown Gora, HRC 407). A few traditional cultivars possessed multiple desirable quality traits (IS 11).

In rainfed based rice farming system of India, rich indigenous diversity still occurs since the modern varieties made very little impact so far. This valuable gene pool could perhaps become a very useful source in the cultivar development for rainfed ecosystem. Thus, an urgent need was felt for their collection, evaluation, conservation and utilization. In-depth study of indigenous cultivars was taken up for various agro-morphological and/or quality traits to identify potential donors for crop breeding.

MATERIALS AND METHODS

The experimental materials comprised 106 rainfed upland and lowland cultivars mostly from Chhotanagpur plateau (Bihar). The genotypes were direct seeded in 1986 (10 g/m²) in augmented design in 3-row plots; 3 m long rows spaced 20 cm apart during wet season at Central Rainfed Upland Rice Research Station, Hazaribagh. The fertilizer N : P : K at the rate of 40 : 20 and 20 kg per ha was provided and healthy crop was raised. A composite random sample of 20 plants was chosen for observations and recording of data on various quality traits.

Representative sample (100 g) was hulled using Satake dehusker and the brown rice was milled in Kett T-2 polisher for 90 seconds (5% milling). The hulling, milling and head rice recovery were computed as reported earlier (Govindaswamy and Ghosh, 1969). Length and breadth were recorded on 10 whole milled rice kernels using dial micrometer (Mitutoyo, Japan). Standard analytical methods were employed for estimating amylose content (Juliano, 1971); alkali digestion value (Little *et al.*, 1958); water uptake and volume expansion (Beachell and

Stansel, 1963) and kernel elongation (Azeez and Shafi, 1966). Range, mean and coefficient of variation (CV, %) were computed to assess the magnitude of variability in different quality characters. Metroglyph and index score method was used to study the diversity in the experimental material (Anderson, 1957).

RESULTS AND DISCUSSION

The range, mean and coefficients of variation revealed considerable variability in the material for most of the quality traits (Table 1). The highest variability was recorded for alkali digestion value followed by head rice recovery and water uptake. The head rice yield ranged from 31.2 to 68.1 per cent with 17.92 per cent of the genotypes showing more than 60 per cent head rice recovery. High variation observed in head rice recovery is of great significance as it is the proportion of head rice rather than total milled out turn. The kernel shape (L : B ratio) ranged from 1.68 to 3.54 and exhibited moderate variability (Table 1). The remaining attributes had low variation. But for hulling, milling recovery and volume expansion, there was lack of inherent variation which was evidenced by their low CVs. This is in agreement with earlier reports (Jennings *et al.*, 1959; Chauhan and Nanda, 1983).

Kernel colour, size and shape varied widely. Among 106 cultivars, 53 possessed short bold and red kernels followed by 33 genotypes with short bold and white kernels. Only three cultivars (*Kalamdani*, HRC 212, *Brown Gora*, HRC 409 and *Sukhawel*, 20 HRC 490) exhibited long slender and white kernels. Predominance of short bold types with red or white kernels was evident (Table 2).

Amylose content and alkali digestion value (gelatinization temperature), the two major determinants of qualities of rice showed intermediate amylose content (20-25%). It ranged from 16.7 to 23.4% with (m 21.08 ± 0.13). However, wide range, 4.5 to 36.0% for this trait in collections from North Eastern Indian hills (Sadananda *et al.*, 1987) and a range of 16.3-28.1% for amylose content of indigenous upland rice cultivars (Hussain *et al.*, 1987) were reported. Since most of the collections in the present study represented a limited geographical area, with perhaps similar preference for rice quality, this might have resulted in restricted diversification. Only 16 of these cultivars had the most desirable combination of these two traits.

Good cooking quality rice is judged by the facts that it should have high water uptake, volume expansion and kernel elongation. Although, limited variation in volume expansion, water uptake and kernel elongation was observed in the present experimental material, twenty seven genotypes exhibited high water uptake (more than 300 ml); the highest being recorded in *Raria* (HRC 268). *Kalamdani* exhibited longest kernels after cooking yet the highest kernel elongation (20.3) was observed in *Sudha* (HRC 432). Seventeen cultivars had kernel elongation of 1.81 or more. Relatively low variation for volume expansion and kernel elongation was earlier reported (Hussain *et al.*, 1987).

Analysis of diversity using metroglyph analysis

Parental diversity plays a vital role in obtaining desirable segregants. This necessitates critical study of the diversity among the genotypes. The D^2 statistics helps in cluster analysis but often it is quite tedious while analysing large number

Table 1. Range, mean and coefficient of variability (%) for different quality traits

Character	Range	Mean $\pm$ SE	CV (%)
Hulling (%)	70.00 - 80.50	77.60 $\pm$ 0.25	3.4
Milling (%)	65.30 - 75.30	70.50 $\pm$ 0.25	3.6
Head rice recovery (%)	31.20 - 68.10	48.20 $\pm$ 1.05	22.4
Kernel length (mm)	4.21 - 7.02	5.63 $\pm$ 0.04	7.6
Kernel breadth (mm)	1.98 - 2.92	2.49 $\pm$ 0.02	7.3
L : B ratio	1.68 - 3.54	2.28 $\pm$ 0.03	12.6
Alkali digestion	2.50 - 5.50	3.22 $\pm$ 0.09	29.5
Amylose content (%)	16.70 - 23.40	21.08 $\pm$ 0.13	6.4
Water uptake (ml)	155.00 - 370.00	262.83 $\pm$ 5.04	19.8
Volume expansion	3.50 - 4.30	3.83 $\pm$ 0.02	4.7
Cooked kernel length (mm)	8.00 - 12.40	9.63 $\pm$ 0.08	8.6
Kernel elongation (mm)	1.49 - 2.03	1.71 $\pm$ 0.01	6.3

Table 2. Classification of genotypes based on kernel size, shape and colour

Type	Frequency		Genotypes
	No.	(%)	
Long bold, white	10	9.43	<i>Pakhiraj</i> (197), <i>Bhojani</i> (269) <i>Dhudhras</i> (271), <i>Br. Gora</i> (298), <i>White Gora</i> (322), <i>Black Gora</i> (364) <i>Rohini</i> (424B) <i>Laloo-14</i> (4578), <i>Early Seetreal</i> (491), <i>Khao Vano Veri</i> (505)
Long bold, red	3	2.83	<i>Tilasar</i> (273), <i>Br. Gora</i> (378), <i>Br. Gora</i> (394)
Long slender, white	3	2.83	<i>Kalamdani</i> (212), <i>Br. Gora</i> (409), <i>Sukhawel 20</i> (490)
Long slender, red	1	0.94	<i>Br. Gora</i> (407)
Medium slender, white	2	1.88	<i>Br. Gora</i> (316, 410)
Medium slender, red	1	0.94	<i>Haskalma</i> (123)
Short bold, white	33	31.13	<i>Saro</i> (188), <i>Patihri</i> (205), <i>Dahia</i> (264), <i>Dahia</i> (266), <i>Raria</i> (268), <i>Nauhia</i> (287), CR 143-2-2 (297), <i>Whitie Gora</i> (303, 308, 310, 312, 313, 315, 317, 320, 321, 323, 325), <i>Br. Gora</i> (371), <i>Black Gora</i> (372, 373), <i>Br. Gora</i> (379, 380, 383, 386, 387, 388, 390), ARC 7046 (426B), <i>Sudha</i> (432), <i>Jhumlakhbiri</i> (518), <i>Lalki</i> (605), <i>Chandragrahi</i> (606)
Short bold, red	53	50.00	<i>Jonga white</i> (140), <i>Jonga</i> (157), <i>Black Gora</i> (159), <i>Br. Gora</i> (160), <i>Karhani</i> (173), <i>Tilasar</i> (190), <i>Jonga</i> (202), <i>Jhunasar</i> (211), <i>Karhani</i> (239), <i>Karhani</i> (240), <i>Br. Gora</i> (270), <i>Ramkel</i> (272), <i>Br. Gora</i> (274), <i>Damodar</i> (275), <i>Br. Gora</i> (280), <i>Karhani</i> (290, 299), <i>White Gora</i> (301, 302, 314, 318, 319, 324), <i>Black Gora</i> (358, 359, 361, 362, 363, 365, 366, 367, 368, 369, 370), <i>Br. Gora</i> (382), NCS-2 (416), PTB-10 (421), <i>Beali B-76</i> (423), <i>Mettasannalu</i> (425), <i>Annapurna</i> (431), <i>Chakkula</i> (433, 433B), <i>Teempathia</i> (441, 441B), <i>Bagri Black</i> (446, 446B), <i>Bagri white</i> (447), <i>Aus</i> 454 (465), <i>Rangpur</i> (466), <i>Cherannuni</i> (467), <i>Dharial</i> (468)

Within parentheses are the Hazaribagh Rice Collection (HRC) numbers for referring the seed source

of genotypes, metroglyph analysis was considered suitable for preliminary grouping of large number of germplasm (Chandra, 1977; Kotaiah *et al.*, 1987).

The head rice recovery and alkali digestion value were considered as the X and Y ordinates and all genotypes were plotted. Five other characters (Table 3) were denoted by rays at different positions of the glyph. The range in each attribute was divided into three classes (Table 3) and represented by different bars (Fig. 1b). The genotypes differed markedly for the various quality traits, in respect of pattern of rays and variability. The scatter diagram (Fig. 1 a,b) revealed that these rice genotypes could be assigned to six complexes.

Table 3. Index score values for some quality traits

Characters	Range	Index score		
		1 (<)	2	3 (>)
Kernel length (mm)	4.22 - 7.22	5.51	5.51 - 6.60	6.60
L : B ratio	1.68 - 3.54	2.00	2.00 - 3.00	3.00
Amylose content (%)	16.70 - 23.40	20.00	20.00 - 25.00	25.00
Water uptake (ml)	155.00 - 370.00	227.00	227.00 - 300.00	300.00
Kernel elongation (mm)	1.49 - 2.03	1.67	1.67 - 1.85	1.85

Group I: This is the largest complex with 29 genotypes with index score of 6 to 11 and mean value low (8.41) and scattered cluster with 1-2 bar pattern for different attributes (Fig. 1a). This group was characterised in intermediate-high gelatinisation temperature (low alkali score) and low head rice yields. The genotypes, in general, had short to medium grains (≤ 6.60 mm).

Group II: Twenty four genotypes with intermediate gelatinisation temperature and moderate head rice recovery represented this group. This group had wide index-score-value range with the highest mean index score (Table 4).

Groups III, IV and V had cultivars with low alkali digestion value (high gelatinisation temperature) and moderate head rice yield; 5, 5 and 6 genotypes respectively formed above three groups.

Group VI: This group comprised five genotypes having intermediate to low gelatinisation temperature and moderate head rice recovery (Fig. 1b). The index score values ranged from 7 to 10 and the mean index score was high (Table 4). The clustering of the genotypes as well as pattern of distribution of quality traits were irrespective of the ecotypic differences. This may probably be due to limited differentiation in quality attributes under two agro-ecological conditions.

Seventy four genotypes could be assigned to one or the other group but 32 genotypes did not belong to any group as they were widely scattered in relation to each other. The cultivars with low or intermediate gelatinisation temperature and high head rice yield were largely scattered (Fig. 1b).

The index score values ranged from 6 (Bagri Black, HRC 446 and HRC 446B) to 12 (Brown Gora HRC 407). The maximum number of genotypes (34) recorded the

Fig. 1 (a). Scatter diagram of metroglyph analysis

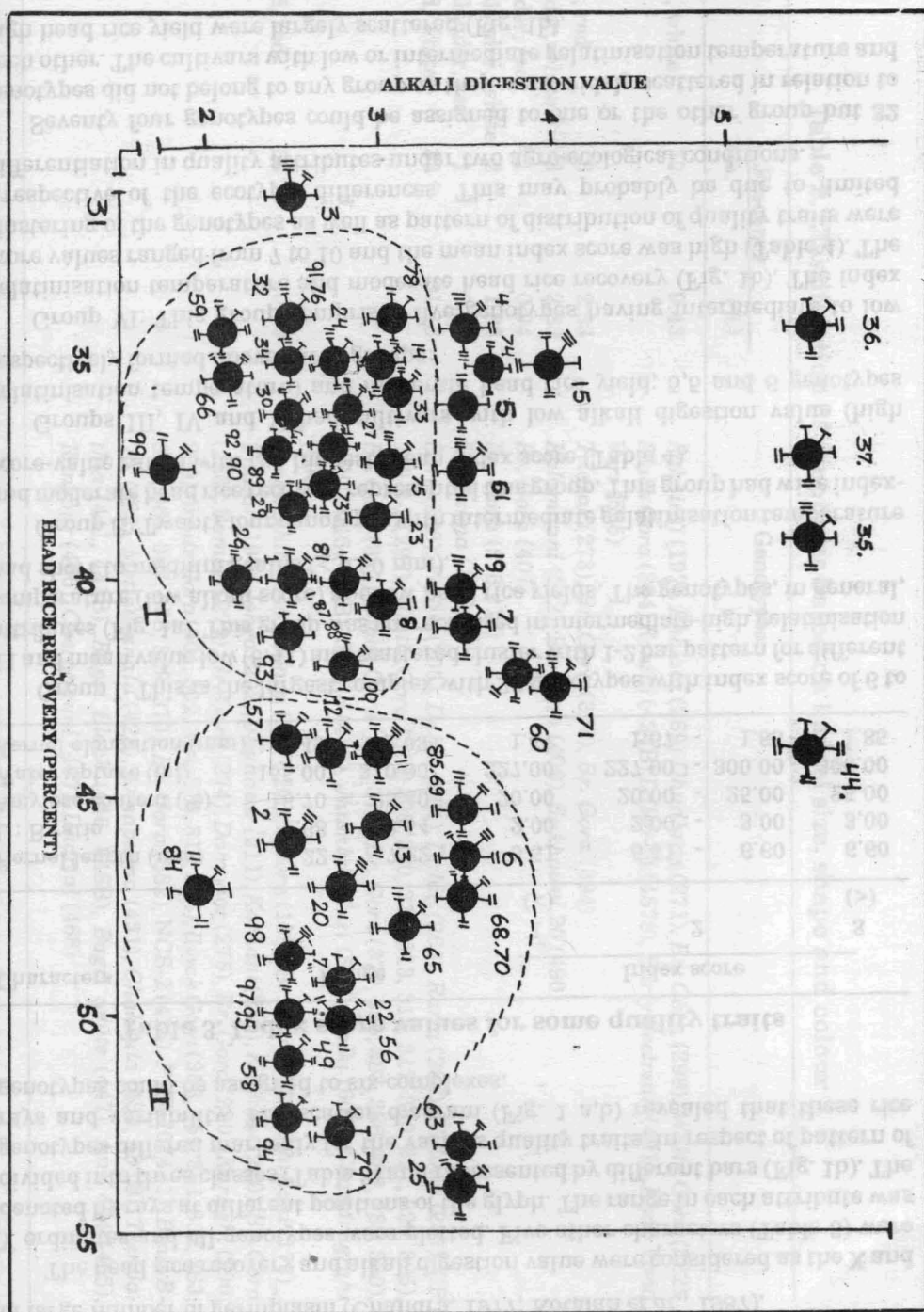


Table 4. Index score values and distribution of genotypes in different clusters

Cluster	Index score value Range	Mean	No. of genotypes	Genotypes
I	6.0 - 11.0	8.41	29	Black Gora (1), White Gora (8), White Gora (14, 18, 23, 24), Black Gora (26, 27, 28, 29, 30, 32, 33, 34), Tilasar (59), Karhani (66), Tilasar (73), Nauhia (75) Karhani (76), Karhani (78), Chakkula (87), Chakkula (88, 89) Parijat (90), Teenpathia (91), Teenpathia (92), Bagri Black (93), Cherannoni (99). Dharilal (100)
II	6.0 - 11.0	9.33	24	Br. Gora (2.6), White Gora (7, 11, 12, 13, 20, 22), Br. Gora (49), Jonga (56), Karhani (57), Saro (58), Karhani (65), Dahia (68), Raira (69), Bhojani (70), NCS-2 (79), Beali B-76 (81), ARC 7046 (84), Annapurana (85), Bagri Black (94), Bagri White (95), Aus 454 (97), Rangpur (98)
III	8.0 - 9.0	8.80	5	Br. Gora (50, 52) Haskalma (54), Mettasannalu (83), Laloo-14 (96)
IV	7.0 - 11.0	9.00	5	White Gora (21), Br. Gora (45, 53), Ramkel (72), Jhul lakhibiri (104)
V	7.0 - 9.0	8.50	6	Black Gora (31), Br. Gora (46), Br. Gora (48), Jonga White (55), Rohini (82), Early Seetareall (102)
VI	7.0 - 10.0	9.00	5	Br. Gora (38), Black Gora (39), Br. Gora (41, 42), Khao Vano Veri (106)

Within parentheses are the Serial no. corresponding to clustering in Fig. 1.

Table 5. Physico-chemical and cooking quality characteristics of some important rice landraces

Genotype	Index Score*	Head rice yield (%)	Kernel length (mm)	L : B ratio	Alkali value	Amylose content (%)	water uptake (ml)	Kernel elongation	Desirable traits
Br. Gora (HRC 160)	11	46.0	5.46	2.00	2.5	20.3	270	1.88	Kernel elongation
Kalandani	11	65.9	7.02	3.54	3.5	22.1	340	1.77	High head rice yield, LS grains, intermediate amylose and GT, high water uptake
Dahia (HRC 264)	11	62.0	5.78	2.38	3.5	20.9	350	1.76	High water uptake
Raria (HRC 268)	11	45.3	5.88	2.10	3.5	20.9	370	1.77	High water uptake
Ramkel (HRC 272)	11	58.1	5.68	2.43	2.8	21.5	350	1.80	High water uptake, head rice yield
Br. Gora (HRC 298)	11	41.2	5.61	2.40	3.5	22.1	210	1.64	Intermediate GT and amylose content
White Gora (HRC 320)	11	47.1	5.82	2.27	2.8	22.8	245	1.92	High kernel elongation and intermediate amylose content
Black Gora (HRC 359)	11	40.0	5.29	2.44	2.5	20.9	330	1.62	High water uptake
Br. Gora (HRC 407)	12	61.0	6.89	3.17	3.5	23.0	240	1.64	High head rice yield, LS grains
Chandragrahi (HRC 606)	11	68.1	5.62	2.26	2.5	22.1	230	1.89	High head rice yield and kernel elongation

Within parentheses are the Hazaribagh Rice Collection (HRC) numbers to indicate seed source

* Cumulative

index score of 9 and 22 had score 10 but they were scattered in different complexes. Some of the important genotypes having cumulative index score of 11 or more out of the maximum score of 15, indicating multiple desirable quality traits (Table 5) could successfully be utilised in the rice quality improvement programme.

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OPIMUM POPPY ALKALOIDS PROFILE IN INDIAN GERMPLAM COLLECTIONS

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A comprehensive study of the alkaloids profile in opium poppy germplasm was undertaken to identify strains rich in morphinane alkaloids. The analysis of major alkaloids was done by liquid chromatographic method which revealed a very high morphinane alkaloids content in some of these strains. These studies further showed that the formation of morphinane alkaloids and isoquinoline alkaloids in opium-gum were negatively correlated. This information could be useful in breeding varieties with high morphine content.

The alkaloids of Opium poppy (*Papaver somniferum* L) are widely used in pharmaceutical industry. The latex obtained from the incised capsules (fruits), gets converted into semi-solid resinous mass called opium gum. Major alkaloids in opium gum are morphinane type (morphine, codeine and thebaine) and isoquinoline type (narcotine and papaverine); however, morphinane type alkaloids are of great medicinal importance.

Identification of strains possessing high latex yield and useful alkaloids is of paramount importance in developing better varieties in opium poppy. With this in view, a study was conducted to determine the latex yield and alkaloid content in some genetic stocks collected by the National Bureau of Plant Genetic Resources (NBPGR) and the results are presented in the paper.

MATERIALS AND METHODS

One hundred and twenty four accessions were collected from the opium growing regions of Madhya Pradesh, Rajasthan and Uttar Pradesh in India. These were evaluated for different characters including latex yield. On the basis of their performance, eight diverse genotypes originating from different states were selected for this study. These included IC 15, IC 19, IC 30 (from Rajasthan); IC 42, IC 83, IC 85, IC 88 (from M.P.); and IC 128 (from U.P.). These alongwith two controls (*Jawahar Afeem* and *Ranjhatak*-conventional varieties grown in M.P. and Rajasthan) were grown, at the Research Farm of NBPGR at Issapur, New Delhi for two crop seasons.

The opium latex was collected during the forenoon from the incised, both lateral and terminal, capsules of the 125-135 days old plants to avoid internal fluctuation in alkaloids content (Fairbairn and Wassel, 1964). The opium gum was processed and analysed on Waters Associates high-performance liquid chromatograph (HPLC) equipped with 6000 A solvent delivery system, 440 absorbance detector, Omniscrite B-5000 recorder, Shimadzu data processor and a reverse phase column with - CN functionality. The extraction procedure, solvent system and liquid chromatographic conditions employed were the same

as developed earlier at the NBPGR (Srivastava and Maheshwari, 1985). The contents of the individual alkaloids, namely morphine, codeine, thebaine, papaverine and narcotine, were calculated on per cent dry weight and yield (mg/plant) basis.

RESULTS AND DISCUSSION

The data on alkaloid content for two consecutive years showed that different accessions were characterised by variable proportions of morphinane, and isoquinoline type alkaloids. The proportion of morphinane alkaloids was always higher than isoquinoline alkaloids.

The data, pooled over the years, indicated that IC 30, IC 42, IC 85, IC 88 and IC 128 were superior in latex gum yield as compared to both the controls under study (Table 1). The total morphinane alkaloids percentages were around 20 per cent in all the accessions except IC 30 and *Jawahar Afeem* with low values of 15.14 per cent and 15.44 per cent respectively. Higher values were obtained in IC 85 (23.20%) and IC 83 (23.07%) as compared to the high yielding control, *Ranjhatak* (20.31%). For morphinane alkaloids yield per plant, all the accessions performed better than both the controls.

Further, higher isoquinoline alkaloids yield was observed in IC 88 (43.98 mg/plant), IC 128 (47.34 mg/plant) and IC 85 (39.64 mg/plant) as compared to both the controls. However IC 42 and IC 83 possessed the isoquinoline alkaloids of almost same level as *Ranjhatak* which gave lower value of 28.89 mg/plant.

The variations in latex yield and alkaloids content in both the years may be ascribed to the effect of environmental conditions (Hofman and Menary, 1980) prevailing during these years. However five accessions (IC 30, IC 42, IC 85, IC 88 and IC 128) were found to be uniformly superior to controls in latex yield. Similarly, high morphinane alkaloids content was noticed (Fig. 1 & 2) in all the accessions except IC 30 in first year (12.50%) and IC 88 in second year (15.50 %).

It is noteworthy that whenever isoquinoline alkaloids content had gone beyond 10 per cent, there was appreciable decline in morphinane alkaloids content of the accessions (Fig. 1 & 2). The biosynthesis of opium alkaloids and variation in different genotypes in alkaloids biosynthesis has been shown to be genetically controlled (Jindra *et al.*, 1966; Bernath and Tetenyi, 1979 and Nyman and Hansson, 1978). Hence, the inverse relationship between morphinane and isoquinoline alkaloids as shown by different selections is possibly due to genetic system controlling the pathway for the formation of these alkaloids.

Since these two pathways are different but linked to each other by common substrate, the biosynthesis of one type of alkaloid will interfere in the formation of other types. Hence, whenever, isoquinoline alkaloids formation takes place more than normal (> 10%), biosynthesis of morphinane alkaloids are affected and these are lowered. Therefore, an improvement in availability of morphinane alkaloids from opium poppy can be brought about by decreasing the isoquinoline alkaloids through appropriate breeding techniques utilising some of the promising collections made from different parts of India.

Table 1. Average yield and alkaloids profile of different accessions in opium poppy

Sl. No.	Accession	Latex yield (mg/plant)	Morphine per cent (mg/plant)	Codeine per cent (mg/plant)	Thebaine per cent (mg/plant)	Total morphine alkaloids per cent (mg/plant)	Narcotine per cent (mg/plant)	Papaverine per cent (mg/plant)	Total Isoquinoline alkaloids per cent (mg/plant)
1.	IC 15	379.88	12.88 (48.91)	5.01 (19.02)	1.81 (6.87)	19.70 (74.80)	05.49 (20.87)	0.02 (0.07)	5.51 (21.94)
2.	IC 19	362.75	13.88 (50.52)	5.13 (18.55)	1.88 (6.84)	20.89 (75.91)	5.69 (21.06)	0.32 (1.25)	6.01 (22.31)
3.	IC 30	489.63	9.63 (46.42)	4.13 (19.87)	1.38 (6.40)	15.14 (72.69)	3.25 (15.27)	0.89 (3.68)	4.14 (18.95)
4.	IC 42	465.25	12.63 (56.12)	4.56 (21.04)	2.00 (9.37)	19.19 (86.53)	3.50 (19.32)	2.38 (11.08)	5.88 (30.40)
5.	IC 83	356.00	16.13 (57.82)	5.25 (19.24)	1.69 (6.20)	23.07 (83.26)	5.49 (19.50)	3.36 (14.74)	8.85 (34.24)
6.	IC 85	427.38	14.38 (60.74)	6.88 (29.56)	1.94 (8.43)	23.20 (98.73)	7.00 (29.92)	2.26 (9.72)	9.26 (39.64)
7.	IC 88	480.75	12.25 (60.43)	4.69 (22.61)	1.38 (6.59)	18.32 (89.63)	6.00 (28.71)	3.39 (15.27)	9.39 (43.98)
8.	IC 128	504.50	13.12 (65.68)	4.60 (22.96)	1.94 (9.81)	19.66 (98.45)	6.63 (33.60)	2.72 (13.74)	9.35 (47.34)
9.	<i>Jawahar</i> <i>Afeem (Control)</i>	403.88	10.75 (43.04)	3.69 (14.70)	1.00 (4.08)	15.44 (61.82)	7.25 (29.14)	3.62 (15.35)	10.87 (44.49)
10.	<i>Ranjhatak</i> <i>(Control)</i>	300.25	14.00 (41.26)	4.81 (14.07)	1.50 (4.41)	20.31 (59.74)	5.69 (23.22)	1.88 (5.67)	7.57 (28.89)

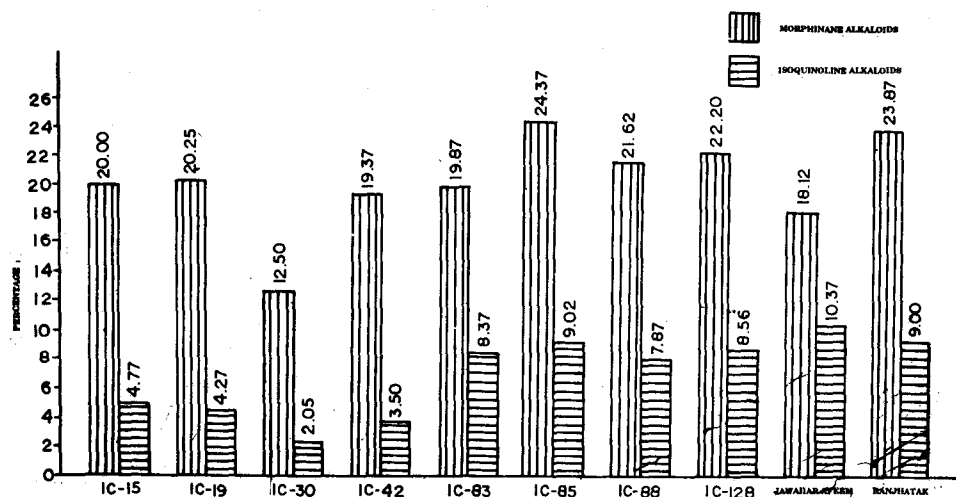


Fig. 1. Alkaloids percentage in different varieties (first year).

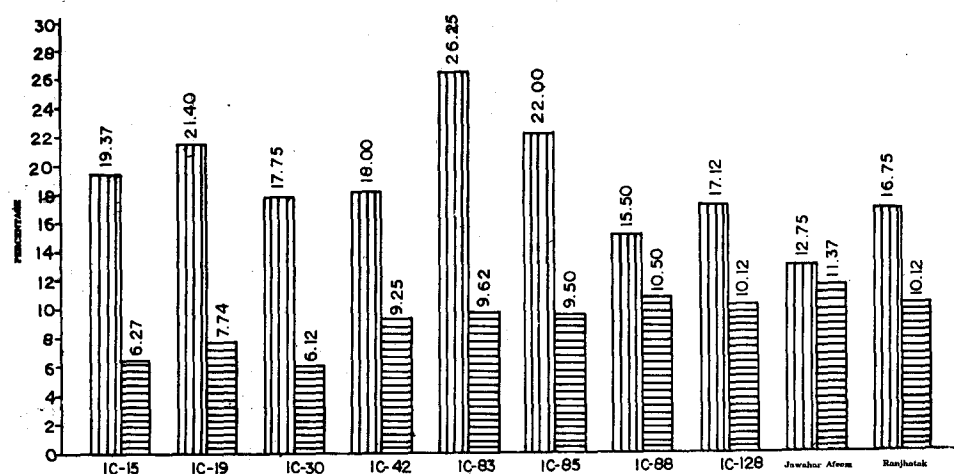


Fig. 2. Alkaloids percentage in different varieties (second year).

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USE OF SEMI-GRAPHICAL TECHNIQUE FOR CLASSIFICATION OF ISABGOL GERMPLASM

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Sixty-one accessions of Isabgol (Plantago ovata Forsk.) including five exotic ones received through the National Bureau of Plant Genetic Resources, New Delhi were classified based on semi-graphical technique. Genetic diversity proved to be more important than geographical diversity. On the basis of index score values and ray patterns of different traits, promising genotypes which could be utilized in heterosis breeding programme included P 96, P 33, HI 8, HI 4, S 11, P 1 and MS for high seed yield; HI 5, Mutant S, EC 41181-37 T (high-yielding, high number of spikes group) and G 1 (medium-yielding medium number of spikes group) for husk percentage. LYHS (low yield high number of spikes), HYLS (high yield, low number of spikes, and HYMS (high yield, medium number of spikes) groups did not contain any genotype.

Isabgol belongs to the family Plantaginaceae and the genus *Plantago* comprises about 200 species, of which 10 occur in India (Anon., 1969). However, *Plantago ovata* is the main source of *isabgol* seed and husk for use in medicine. Sixty-one accessions of this crop were introduced through National Bureau of Plant Genetic Resources (NBPGR), New Delhi. This paper deals with the grouping of *isabgol* germplasm lines from different geographical regions by using a simple semi-graphical technique.

MATERIALS AND METHODS

A collection of 61 *isabgol* accessions, including 5 exotics, were raised in replicated plots during November, 1988-89. The plots comprised two rows, each 3 m long, with 25 cm inter-row and 5 cm inter-plant spacing. The data on five plants from each plot were recorded for plant height (cm), number of spikes per plant, spike length (cm) and seed yield per five plants (g). Husk percentage was analysed in the laboratory by simple milling process using 100 g sample of each strain. Husk yield of five plants was calculated by the formula :

$$\text{Husk yield (HY)/five plants (g)} = \frac{\text{Husk percentage (HP)} \times \text{seed yield of five plants (g)}}{100}$$

The mean values were used to construct metroglyph diagram following the semi-graphical method (Anderson, 1957). In the metroglyph diagram, each accession was represented by small circle (empty circle for indigenous and filled circle for exotic strains), the x-ordinate being seed yield and y-ordinate being the number of spikes per plant. These two traits were chosen to represent x, y-axis because of their wide genetic variability. The other characters were represented as rays on the

circles. The index values determined the length of rays: no ray, short ray or long ray. These index values were obtained by allotting numerical values (0, 1 or 2) to three grades of expression recognised for each character; while index score for each strain was estimated by summing up the index values of all the characters.

RESULTS AND DISCUSSION

The variability pattern of the present *isabgol* collection as indicated by metroglyph diagram (Fig. 1), seemed to be quite interesting. Superimposed on the metroglyph depiction were the groups obtained, primarily on the basis of yield and spike producing ability. On the basis of seed yield potential, the lines were grouped into three broad categories, viz., Low, medium and high yielding groups. The seed yield per 5 plants of lines in low yielding group ranged from 3 to 6 g, in medium yielding group 6.1 to 10 g and in high yielding group 10.1 to 13 g (Table 1). The strains in each group had mostly similar characters.

The low-yielding group included 3 exotic and 18 indigenous strains. Index score of low yielding lines varied from 7 to 12 (Fig. 2). Overall mean performance (Table 2) revealed that the low yielding group was characterized by dwarf plants, short and less number of spikes.

The cultivars included in medium-yielding group were indigenous except one. Majority of strains (35) belonged to this category and the index score of this group ranged between 9 to 15. However, few genotypes of low yielding and high yielding groups inter-mixed with respect to their index scores. All the traits observed in this group depicted intermediate expression as compared to low and high yielding group.

The high yielding group was represented by 9 indigenous and one exotic strain. In addition to the highest expression exhibited by all the traits, number of spikes depicted the maximum increase in this group. The performance of 10 high yielding genotypes for various traits has been given (Table 3). Among them, four strains, viz., HI 5 (12), S 11 (22), P 1 (26) and Mutant S (49) obtained an index score of 17. HI 4 (18) though had an index score of 15, produced maximum seed yield (Table 3). This was due to less husk percentage of HI-4 as compared to above mentioned four genotypes. Husk percentage was the maximum in HI 5 (34.0%) followed by exotic strain EC 41181-37 T (32.9%) and Mutant S (32.5%).

On the basis of number of spikes per plant, the collections were classified into three groups, viz., low (LS), medium (MS) and high number of spikes per plant (HS). Most of the strains included in LS group were poor yielders. The MS group consisted of 18 medium yielding and 7 low yielding accessions. Ten high and 8 medium yielding cultivars formed the HS group. Apparently, the grouping of lines based on spike producing ability was more or less similar to that based on yielding ability.

The metroglyph analysis proved effective in classifying the present *isabgol* germplasm collection into distinct groups. It was demonstrated in wheat that precise classification by metroglyph analysis can be obtained when the maximum variability exists for two characters selected to represent x and y ordinates (Jain *et al.*, 1978). Additional information gained from the metroglyph analysis in

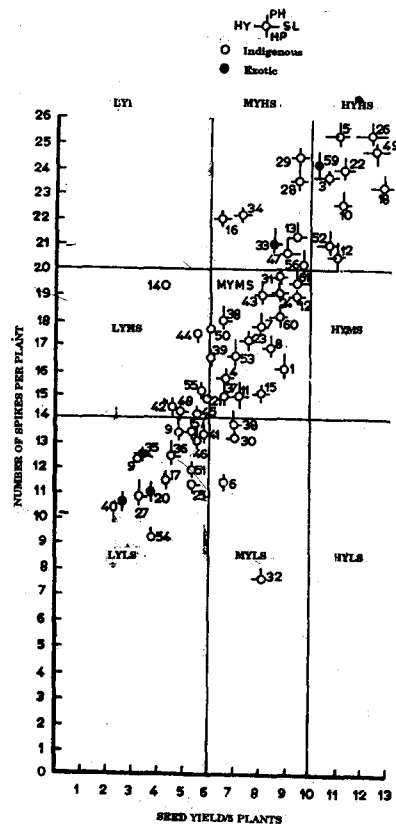


Fig. 1. Metroglyph diagram showing the distribution of the characters among *isabgol* strains.

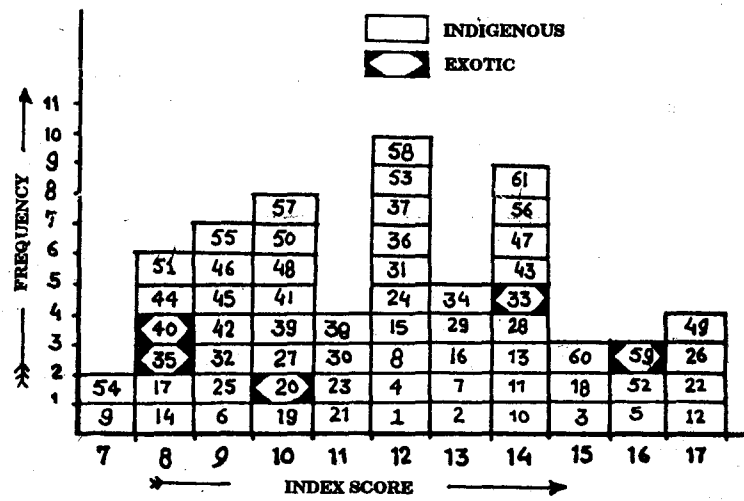


Fig. 2. Frequency distribution of index score values of *isabgol* accessions

Table 1. Range of variability and class intervals of morphological traits in *Isabgol*

Character	Range of variability	Score 1		Score 2		Score 3	
		Range	Sign	Range	Sign	Range	Sign
Plant height (cm)	26.1 - 36.3	≤ 28.0	0	28.1 - 32.0	0	≥ 32.1	0
Number of spikes per plant	9.3 - 25.4	≤ 14.0	-	14.1 - 20.0	-	≥ 20.1	-
Spike length (cm)*	2.4 - 4.1	≤ 3.0	0	3.1 - 3.7	0	≥ 3.8	0
Seed yield/five plants (g)	3.0 - 12.7	≤ 6.0	-	6.1 - 10.0	-	≥ 10.1	-
Husk percentage	22.8 - 35.1	≤ 28.0	0	28.1 - 32.0	0	≥ 32.1	0
Husk yield/five plants (g)	0.82 - 4.06	≤ 2.0	0	2.1 - 3.0	0	≥ 3.1	0

Table 2. Group means for *Isabgol* collection classified on the basis of yielding potential and number of spikes per plant

Groups	Plant height (cm)	No. of spikes per plant	Spike length (cm)	Seed yield per five plants (g)	Husk percentage	Husk yield per five plants (g)
Low yielding	30.52	14.38	2.89	4.81	28.97	1.44
Medium yielding	32.61	17.01	3.17	7.83	29.74	2.33
High yielding	33.12	23.24	3.51	11.31	30.46	3.44
Low number of spikes per plant	31.67	12.08	2.84	5.71	28.32	1.67
Medium number of spikes per plant	31.40	16.83	3.14	6.55	30.23	1.98
High number of spikes per plant	32.92	22.60	3.42	9.93	30.46	3.44

Table 3. Index (in parentheses) and mean values of high-yielding lines for various characters

S. No.	Geno- types	Plant height (cm)	Spikes per plant	Spike length (cm)	Seed yield of five plants(g)	Husk percentage	Husk yield of five plants(g)	Index score
1.	P 96	31.5(2)	23.9(3)	3.49(2)	10.50(3)	29.70(2)	3.12(3)	15
2.	P 33	32.9(3)	25.4(3)	3.64(2)	11.00(3)	31.30(2)	3.34(3)	16
3.	HI 8	34.4(3)	22.7(3)	3.76(2)	11.00(3)	25.75(1)	2.83(2)	14
4.	HI 5	34.0(3)	20.7(3)	3.47(2)	10.85(3)	34.00(3)	3.69(3)	17
5.	HI 4	35.8(3)	23.3(3)	3.68(2)	12.75(3)	27.15(1)	3.46(3)	15
6.	S 11	33.2(3)	24.1(3)	3.75(3)	11.25(3)	31.70(2)	3.57(3)	17
7.	P 1	34.7(3)	25.4(3)	3.82(3)	12.25(3)	29.80(2)	3.65(3)	17
8.	Mutant S	29.5(2)	24.8(3)	3.90(3)	12.50(3)	32.50(3)	4.06(3)	17
9.	MS	32.5(3)	21.0(3)	3.33(2)	10.75(3)	29.80(2)	3.20(3)	16
10.	EC 41811 37 T	32.7(3)	24.2(3)	2.81(1)	10.25(3)	32.90(3)	3.37(3)	16
Range		29.5-35.8 (2) (3)	20.7-25.4 (3) (3)	2.82-3.90 (1) (3)	10.25-12.75 (3) (3)	25.75-34.0 (1) (3)	2.83-4.06 (3) (3)	14-17

the present study was that the lines within medium and high yielding groups showed variation for important attributes such as husk percentage, spike length and husk yield. It was evident that the hybridization between lines within medium and high yielding groups could be useful. The index score reflected the mean performance of strains for seed yield. Generally, high index scorers were also the high yielders.

The results indicated that metroglyph and index score analysis could be effectively and efficiently utilized in the preliminary classification of germplasm. Such a classification aids in careful choice of parents with wide genetic bases for successful hybridization programme.

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CULTIVATED CUCURBITS AND THEIR WILD RELATIVES IN INDIA

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Cucurbits are a highly evolved group of plants, widely cultivated as vegetables and fruits. Eighteen out of about 100 species known to occur in India, are cultivated. Many wild species and weedy relatives are important and could be utilized for improving the cultivated types through breeding approaches. The origin, distribution, classification, morphology and climatic adaptation of cucurbits have been reviewed. A detailed account of the available diversity, distribution pattern and economic uses in respect of cultivated cucurbits has been enumerated. The role of wild relatives for improving the potential of cultivated types has been emphasized.

There are 110 genera and 640 species in the family Cucurbitaceae (Willis, 1982) which are distributed primarily in the warmer parts of the world. In India, about 100 species of cucurbits under 36 genera are known so far (Chakravarty, 1982). Out of which, 25 species are endemic and eighteen species belonging to 10 genera are commonly cultivated as vegetables and fruits. These include pumpkin, squash, vegetable marrows, gourds, melons, watermelons, cucumber and several lesser known crops. The most important nutritional contribution of the fruits are vitamins and minerals especially vitamins A and C. The food value and nutritional quality of different Indian cucurbits revealed their usefulness for various purposes (Gopalan *et al.*, 1982 or Seshadri, 1986). These could be used for food either fresh, cooked, pickled, candied and curried. The young leaves and flowers of several species are edible and rich source of vitamins and minerals. The species with fruits having a hard, tough rind are used for containers, cutlery, musical instruments and ornaments etc. In this paper, an attempt has been made to review the available information on origin, distribution, growth habit and economic uses of cultivated cucurbits and their wild relatives occurring in India.

Classification, Origin, Distribution, Morphology and Climatic Adaptation

Taxonomy and classification

The taxonomy and classification of this group (Family - Cucurbitaceae) including infra-specific categories has been discussed by several workers (Cogniaux, 1881; Jeffrey, 1980; Chakravarty, 1982). The seed morphology of 24 species, belonging to 22 genera of Indian cucurbits which was studied by Chakravarty and Hore (1979) could be used as an aid to identify the species. However, the realistic classification of the cultivated species and their forms is too difficult to ascertain from seed morphology because of wide range of variations within the species. This could possibly be due to the domestication, selection and gradual improvement of the crop.

Origin and distribution

The distribution of this group of plants is found almost throughout the world either in indigenous or introduced form. The centres of origin of various cultivated species are located mainly in Asia, Africa and American continents (Zeven and Zhukovsky, 1975; Whitaker and Bemis, 1976; Esquinas-Alcazar and Gulick, 1983). The study of chromosome number of various species of both cultivated and wild cucurbits was done by different authors from time to time which has been compiled and well documented by Fedorov (1974). The cytological investigations also helped in recognising the centres of diversity of *Cucumis* groups bearing chromosome number $2n = 14$ and $2n = 24$ (Jeffrey, 1980.). Similarly, the earlier concept about the relationship between *Citrullus lanatus* and *Praecitrullus fistulosus* was disproved by cytological studies (Khoshoo and Vij, 1963).

The cultivated species of cucurbitaceae include plants of both New and Old World origin (Esquinas-Alcazar and Gulick, 1983). Genus *Cucurbita* is believed to have originated from central Mexico and west-central part of Latin America as evidenced from the fossil records (Whitaker, 1983). There are 26 species of *Cucurbita* distributed throughout the world (Whitaker and Bemis, 1976). Out of these, 5 species are domesticated and cultivated of which 4 are popularly cultivated in India.

Morphology

Most cucurbits are trailing herbs or undershrubs with tendrils. Habit wise, these are either monoecious or andromonoecious. But gynomonoecy, androgynomonoecy, androecy, gynoecy and hermaphrodite flowers are also found in some species. Dioecious habit is also prevalent in some of the species. Thus, they are open pollinated, self-compatible and genetic variation exists within a single cultivar. Different species vary in shape and size of their leaves besides, flower size and colour, fruit shape, size, colour variations, dehiscence and their seed morphology.

Climatic adaptation

The growth and development of different species show varying degrees of sensitivity to temperature and humidity. Melons and watermelons prefer hot dry climates. Cucumbers grow well in moderate warm conditions. Both have disease problems in areas of high humidity. On the contrary, the species of *Cucurbita* generally are well adapted to low and cool temperatures. In Indian conditions, *Sechium* grows very well between 800 to 2000m altitude. However, the germplasm of various cucurbits collected from the north-eastern region have shown wider adaptability.

Cultivated cucurbits

Among the different species of cucurbits, *Cucurbita* is the only dominant genus with several major cultivated species, namely, *Cucumis*, *Citrullus*, *Momordica*, *Luffa*, *Lagenaria*, *Benincasa*, *Praecitrullus*, *Trichosanthes* and *Sechium* (Table 1). The diversity available in important cucurbits, their distribution pattern and the economic uses are briefly given species-wise.

Table 1. Major Cucurbitaceous crops in India

Species	Common English name	Native area*	Chromosome number (2n)
<i>Benincasa hispida</i> (Thumb.) Cogn.	White gourd	Asian subtropics	24 (Varghese, 1973)
<i>Citrullus lanatus</i> (Thumb.) Mats. & Nakal	Water melon	South Africa	22 (Shimotsuma, 1958)
<i>Cucumis melo</i> L.	Melon	Tropical and South Africa	24 (Vasil, 1962)
<i>Cucumis sativus</i> L.	Cucumber	India	14 (Roy and Mishra, 1962)
<i>Cucurbita ficifolia</i> Bouche**	Fig leaf gourd	Mexico, Central & Northern South America	40 (Whitaker, 1956)
<i>Cucurbita maxima</i> Duch. ex Lam.	Winter squash	Northern South America & Central America	40 (Bhaduri and Bose, 1947)
<i>Cucurbita moschata</i> (Duch. ex Lam.) Duch. ex Poir.	Pumpkin	Mexico, Central America	40 (Pearson <i>et al.</i> 1951)
<i>Cucurbita Pepo</i> L.	Marrow pumpkin	North America, North of Mexico city	40 (Whitaker 1930, 1956)
<i>Lagenaria siceraria</i> (Molina) Standl.	Bottle gourd	Africa, the Americas	22 (Whitaker, 1930)
<i>Luffa acutangula</i> (L.) Roxb.	Ribbed gourd	India and East Asia	26 (Bhaduri and Bose <i>l.c.</i>)
<i>Luffa cylindrica</i> (L.) M. Roem.	Sponge gourd	Tropical world especially Japan and Brazil	26 (Whitaker, 1933)
<i>Momordica charantia</i> L.	Bitter gourd	South & SE Asia	22 (Riley, 1960)
<i>Momordica cochinchinensis</i> (Lour.) Spreng.**	Sweet gourd	SE Asia & Pacific	.
<i>Momordica dioica</i> Roxb. ex Willd.**	Prickle gourd	Subtropical Asia	28 (Richharia and Ghosh, 1953)
<i>Praecitrullus fistulosus</i> Pang.	Round melon	India	24 (Khoshoo and Vij. <i>l.c.</i>)
<i>Sechium edule</i> (Jacq.) SW.***	Chayote, Chow chow	Tropics and Latin America	28 (Varghese, <i>l.c.</i>)
<i>Trichosanthes anguina</i> L.	Snake gourd	South & SE Asia	22 (Nakajima, 1936)
<i>Trichosanthes dioica</i> Roxb.	Pointed gourd	Karnataka & West Bengal in India	22 (Bhaduri and Bose, <i>l.c.</i>)

* After Zeven and Zhukovsky (*l.c.*), Esquinas-Alcazar and Gulick (*l.c.*)

** Perennial

*** Semi-Perennial

Winter squash (*Cucurbita maxima*)

Among the cucurbits, *Cucurbita maxima* is noted for its extremely rich diversity. Polymorphic variations in the fruit morphology (shape, size, both primary and secondary skin colour, surface, weight etc.) are remarkable within the species itself. Variations are much prominent in cultivars, possibly due to the result of selection (Whitaker and Robinson, 1986). In the course of time, the species was introduced in the old world countries. India and Myanmar (Burma) are considered secondary centres of diversity for *Cucurbita maxima* (Equinas-Alcazar and Gulick, 1983). Remarkable variations were observed in fruit shape, size, external surface, shell thickness, skin and flesh colour of *Cucurbita maxima* that are grown in north-eastern region of India. It grows in different ecological situations from tropical to temperate climate. In Nagaland, some old obsolete varieties and primitive cultivars are still existing which seem to be the rare and exceptionally useful material.

Pumpkin (*Cucurbita moschata*)

Diversity in *Cucurbita moschata* is somewhat less than that observed in *C. maxima* in India. Apparently, it differs from *C. maxima* in respect of presence or absence of stem bristles, leaf texture, nature of peduncle and calyx morphology. Fruits in *C. moschata* are usually oblong and constricted at the middle. Based on seed size and margin, species is readily distinguishable from *C. maxima*. The species is cultivated throughout tropical and sub-tropical regions of India.

Marrow pumpkin (*Cucurbita pepo*)

Cucurbita pepo is characterised by its 5-angulate, grooved, hard peduncles and relatively smaller fruit size than other *Cucurbita* species. Variations are prevalent within the species in respect of fruit shape and colour. Unripe fruit is mostly preferred as vegetable during the rainy season when it is available. The species thrives well under tropical climatic conditions.

Fig leaf gourd (*Cucurbita ficifolia*)

This perennial, short-day species is basically a Mexican species which was introduced in the Meghalaya state where it naturalised very well. Though human consumption of the fruits is very limited in Meghalaya, it is largely fed to the domestic animals like pigs, cows etc. The species is least variable and mostly restricted in its habitat.

Cucumber (*Cucumis sativus*)

Out of 6 species of *Cucumis* found in India, *Cucumis sativus* is widely cultivated. Cytological studies revealed that the species under the genus *cucumis* belong to two distinct geographically isolated groups, i.e. Asiatic group and African group (Seshadri 1986). Species bearing chromosome number $2n = 14$ are all of Himalayan origin while species of $22n = 24$ are basically originated from tropical and south Africa. Cucumber (*Cucumis sativus*) having chromosome number $2n = 14$ originated in India. This species has been cultivated since 3000 years (De Candolle, 1882) all over India and has two forms (i) creeping form - cultivated in the fields

during hot season and (ii) climbing form-cultivated during the rainy season. Morphologically, they differ in fruit size.

The closely related wild species (*Cucumis hystrix* Chakrav.), also grows in Meghalaya which, however, may be a weedy form of the cultigen. This creeping plant with small, echinate, oblong fruit with bitter taste can be a valuable material for breeding purpose with the cultivated cucumber, since they are well adapted in wild habitat at 900-1500 m altitude and resistant to diseases and pests.

Muskmelon (*Cucumis melo*)

This species is also widely cultivated in India. Its centre of origin is supposed to be Africa (Zeven and Zhukovsky, 1975) where many wild species of the genus frequently occur. Domestication of muskmelon may have occurred independently in India (Esquinas-Alcazar and Gulick, 1983) especially, north and central India where many forms of melons differing in size, skin and pulp colour and taste are cultivated.

Watermelon (*Citrullus lanatus*)

This species has originated in tropical and west Africa and gradually spread to India in very early times. It is now the centre of diversity for cultivated forms. Its wild form occurs in semi-desert and sandy areas of Kalahari desert (Seshadri, 1986). Botanically, the species has several forms and the variation exists in size, shape, colour and sweetness of the pulp.

White gourd (*Benincasa hispida*)

The centre of origin and diversity of white gourd or wax gourd is south-east Asia and Indo-China and it is distributed from Japan to India. This monotypic species is a monoecious vine bearing large green fruits, globose-cylindrical in shape and covered with thick epicuticular wax. It is cultivated in tropical and sub-tropical regions of India and has a wide variability among its cultivars especially, in fruit size and shape and seed colour. It is widely used in northern India in preparing dry sweetmeat from the mature fleshy parts of the fruits. In Meghalaya, the species is cultivated in the *jhoom* land which gives a very good yield.

Bottle gourd (*Lagenaria siceraria*)

Archaeological records indicated that this species was present in Peru (Latin America) around 12,000 B.C. (Esquinas-Alcazar and Gulick, 1983). There is a good evidence of its origin in Africa (Jeffrey, 1980). This white-flowered gourd has a long history of cultivation in both the New and Old World and perhaps a very important crop for the primitive societies which is documented by well preserved remains of seeds, peduncles and occasionally intact fruits. It is widely cultivated in the warmer parts of India as a vegetable. The hard fruit-shells when ripe are used as containers for storing liquids and food, as eating utensils and for musical instruments like *Sitar* and *Veena*. Extensive variability exists in this species in respect of shape, size, colour and weight of the fruit in the north-eastern region of the country.

Ribbed gourd, sponge gourd (*Luffa* spp.)

The probable centre of origin and the primary gene centre for *Luffa* is in India. Out of total 9 species present all over the world, 7 occur in India. Among them, *Luffa acutangula* and *L. cylindrica* are commonly cultivated. They are monoecious vines bearing ridged or smooth fruits, which contain many black seeds at maturity. Young fruits are used as a cooked vegetable, while dried skeletonised fruits are used as bath-sponge. Taxonomically, there are two varieties of *Luffa acutangula* i.e. var. *acutangula* and var. *amara* (Chakravarty, 1982) and they have been differentiated on the basis of size and shape but variability occurs among cultivars in their size and taste.

Bitter gourd (*Momordica charantia*)

This species has originated in the tropics of Old World and occurs widely in the tropics of Asia. A monoecious vine, variable in the form of its fruits. The fruit is characterized by its tuberculate-muricate skin and the sculptured seed surface. Young fruits are used in the tropics as a vegetable, in pickles, curries and salads. It is also eaten during an epidemic of small-pox as it is supposed to have a preventive effect. In India, *M. charantia* var. *muricata* is often seen in wild condition also, while the var. *charantia* is fully domesticated. The fruits and seeds of bitter gourd exhibit wide variations within the Indian sub-continent.

Sweet gourd (*Momordica cochinchinensis*)

This species is an Indo-Malayan species extending its distribution upto Pacific Islands. The fruits are generally small and cultivated in kitchen gardens during the winter. The green fruits are a favourite vegetable of the people of north-east India.

Prickle gourd (*Momordica dioica*)

Prickle gourd is thought to have originated in India and gradually spread to adjacent Asian countries, namely, Burma, Sri Lanka and China. The species is characterized by its tuberous roots which are used as a sedative during fever. The green fruit is extensively used as a vegetable by cooking or frying. The plant usually propagates through root-stock which can establish easily.

Round melon (*Praecitrullus fistulosus*)

Round melon (*Tinda*) is confined to north and north-western regions of India and Pakistan which seems to be the centre of origin of the species. Morphologically and cytogenetically, the taxon is different from its allied species *Citrullus lanatus*. The species is cultivated in north and north-eastern regions of India for the fruits which are used as vegetable.

Chayote or chow-chow (*Sechium edule*)

This is commonly known as squash in India which is entirely different from squash of western countries. For the people of western countries squashes are the tender/growing fruits of *Cucurbita* which are much relished. *Sechium* is monotypic

genus and its centre of origin and diversity is in tropical America. This introduced species is cultivated in India especially in sub-tropical to temperate hilly region. This monoecious vine having one-seeded fruit is an unusual character among the cucurbits. The unripe fruits and tender shoots are used as a vegetable which flourishes during the rainy season. Large tuberous starchy roots are used as food. The fruits, which contain 92% water have a low nutritive value. It grows abundantly throughout the eastern Himalayas, both as cultivated and wild. Considerable variability exists in the fruits in size, shape, colour and surface. The species can propagate either through mature fruit (viviparous germination) or viable root-stock.

Snake gourd (*Trichosanthes anguina*)

This species is cultivated in India during the rainy season and its centre of diversity extends from India down to Australia. The fruit is characteristically long (upto 1.5 m), pipelike, fleshy, often twisted with 7-8 white stripes along its length when green. The young fruit is largely used as a vegetable either boiled or in curries. Variation in the fruits i.e. length, diameter, colour and number of stripes occurs within the species.

Pointed gourd (*Trichosanthes dioica*)

India is the centre of diversity of pointed gourd. It is extensively cultivated in the warmer parts of the country. Plants are dioecious and normally grown in rainy season. The fruits are commonly used as vegetable. Several cultivated forms differing in size, shape and markings of the fruit are common in India. The occurrence of wild and semi-wild forms in the plains of Assam indicates that it might have originated in this area.

WILD RELATIVES OF CUCURBITS

There are several wild relatives of cultivated cucurbits which have the potential to contribute specific desirable genes for bringing spectacular improvements in the cultivated cucurbits. Wild relatives of major cultivated cucurbits and the details about their distribution, reproductive behaviour, chromosomal status and other characteristics are given in Table 2. A few species, namely, *Cylanthra pedata*, *Gymnopetalum cochinchinensis* and *Hodgsonia macrocarpa* are important but still underexploited and need improvement for large scale domestic use. Interspecific crosses between the cultivated and their allied wild species or domestication of naturally occurring wild species through the manipulation of different cultural practices offer a good scope for developing disease resistant and stress tolerant varieties. Indeed, the wild relatives of cultivated species could play an important role in this respect because these can adapt themselves and survive well against natural adversities. The genes responsible for these traits are still untapped and need to be incorporated in the cultivated types through appropriate breeding procedures

Table 2. Wild relatives of major cultivated Cucurbits in India

Wild species	Distribution	Sex type	Chromosome No. 2n) with authority	Remarks
1. <i>Citrullus colocynthis</i> (L.) Schrad.**	Punjab, Rajasthan, Andhra Pradesh, Tamilnadu	Monoecious	22 (Whitaker, 1933)	Essentially a desert plant; readily crosses with <i>C. lanatus</i>
2. <i>Coccinia grandis</i> (L.) Voigt.***	Rajasthan, U.P., Bihar, W.B., Gujarat, A.P., Orissa, Tamilnadu, Kerala	Dioecious	22 (Bhaduri and Bose, l.c.)	Though synonymous with cultivated 'Kundri' (i.e. <i>C. indica</i> W.A.) but differs in leaf lobation, texture and fruit size. However, the wild and cultivated species are allied and closely related with each other.
3. <i>Cucumis hystrix</i> Chakrav.*	Meghalaya, Mizoram	Monoecious	—	An endemic species of north-eastern region of India. Very limited occurrence. Normally found over 900 m altitude. Resistant to pests and disease.
4. <i>Cyclanthera pedata</i> (L.) Schrad.*	Medium altitude of Meghalaya and Uttar Pradesh	Monoecious	32 (Whitaker, 1933)	Basically, the species is exotic. This semi-wild fruit has been introduced in India and domesticated very well in medium to high altitude (800 to 1500m) and gives relatively productive yield.
5. <i>Gynnopetalum cochinchinensis</i> (Lour.) Kurz.*	Andhra Pradesh, Arunachal Pradesh, Bihar, Assam, Manipur, Meghalaya, Sikkim, Tripura U.P. and West Bengal	Monoecious/ Dioecious	22 (Islam and Saha, 1951)	Wildly growing species and may be considered as underutilized plant. The unripe bitter fruits used rarely as vegetable by the tribes of north-eastern region.
6. <i>Hodgsonia macrocarpa</i> (Bl.) Cogn.**	Arunachal Pradesh, Meghalaya Mizoram and Sikkim	Dioecious	—	Grows wildly at lower altitude or foot hills. This under-exploited, less known plant yields oil from its seeds, but the fruits pulp is poisonous
7. <i>Trichosanthes cucumerina</i> L.*	Throughout India	Monoecious	22 (Roy and Mishra, l.c.)	Closely related to cultivated <i>T. anguina</i> , but differs in fruit length, shape and absence of stripes on fruit surface

* Annual

** Perennial

*** Semi-perennial

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Short Communication

SEED REGENERATION IN PEARL MILLET

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Pearl millet is a highly cross pollinated crop. Due to lack of space for maintaining perfect isolation distance (1000 m) during the main cropping season, seed regeneration of several varieties and populations of pearl millet can be undertaken by planting each population in large plots ($>2500 \text{ m}^2$) in square fields, discarding the border rows of 6-8 m on all the 4 sides followed by grid mass selection to represent equally all the component genotypes in the population. This system not only maintains mean performance of the populations with much ease but reduces possible genetic losses that may be caused by cooler climate, unidirectional winds representing unfavourable and a typical environment in the off-season.

In pearl millet, there is a problem of adequate space for obtaining recommended isolation plots at 1000 m apart during the main cropping season for seed regeneration. Undertaking seed multiplication by delayed planting with time isolation during the main cropping season causes loss of vigour and increased incidence of diseases and pests. Cooler climate during dry-season accompanied with occasional heavy unidirectional winds (east-west) causes unidirectional pollen flow and hence hinders random mating. This results in genetic drift with changes of gene frequencies in the population (Mather, 1973; Wallace, 1968). Lack of assured irrigation facilities in many dry areas may not permit satisfactory off-season crop growth. To examine these aspects, seeds of four varieties and composites were regenerated in the rainy season 1981 and 1982 in large plots of 3000 m^2 under random mating without recommended isolations, and during the dry season 1982-83, with perfect isolation. The performance of the crops raised from these three seed lots has been reported in this paper.

The materials for the present study comprised of three pearl millet varieties, namely, ITMV 8001, ITMV 8003, ITMV 8004 and a composite Souna Mali X Ankutess, developed by the ICRISAT-Niger cooperative programme at the National Agronomic Research Center (CNRA), Maradi, Niger through a population breeding programme. Two seed lots of these varieties and composite were produced by random mating without recommended isolation grown in adjacent fields during the rainy season 1981 and 1982. In this system, the large plots of 3000 m^2 were sown with each variety and composite during normal cropping (rainy) season and any shibra plants (intermediate between cultivated and wild millet) growing in these fields were removed before they shed pollen.

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Ear heads of downy mildew (*Sclerospora graminicola*) susceptible plants were also removed before they shed pollen. At maturity, two heads/hill were harvested from the central rows by eliminating 5m wide border hills on all the 4 sides of the plot. During dry season 1982-83, one seed lot of each of the varieties and composite was also produced by growing the crops in perfect isolated plots with no possibility of pollen contamination.

The varieties were evaluated in a randomised complete block design with 3 replications at Maradi and Sadore in the Republic of Niger, West Africa, during the rainy season 1983. Each treatment was sown in hills, in 8 rows of 5m length at a distance of 1m x 0.50m. Two plants/hill were maintained by thinning, 20 days after sowing. The observations were recorded on the central 4 rows leaving 2 border rows on each side of the plot, on characters such as days to 50% flowering, plant height (cm), head length (cm) and grain yield (kg/ha).

The performance of the crop raised from different seed lots at two locations, Maradi and Sadore, in the main pearl millet growing areas of the Republic of Niger, is summarised in table 1. At Maradi, no significant influence of time of seed production was noticed for days to 50% flowering except for composite Souna Mali x Ankutess where for the seed lot produced during rainy season 1982, 4 days delayed flowering was observed than 1981 rainy season seed lot. In all other seed lots and varieties, the difference in days to 50% flowering were close to least significant difference of 1 day. In the trial at Sadore, it was observed that the seed production during dry-season unfavourably influenced flowering time (delayed) for ITMV 8001 and ITMV 8003. The influence on two other populations namely ITMV 8004 and comp. (Souna Mali x Ankutess) was non significant. When the mean of the two locations was compared, the similar trend was noticed.

The differences in height of the plants produced by different seed lots for ITMV 8001 and ITMV 8003 were non-significant at Maradi indicating no effect of time of seed production on this character. This character favourably changed (reduced plant height) for ITMV 8004 for the seed lot produced during rainy season 1982 which might have been due to selection for reduced plant height. At Sadore also, favourable effect of seed production during dry-season with perfect isolation and during rainy season 1982 was noticed for ITMV 8004 for the plant height. No significant influence of time of seed production was noted for any other experimental varieties or composites included in the present study for this character.

In the trial at Maradi, the significant influence of the time of seed production on head length was noted only in variety ITMV 8001 where shift of head length was observed towards increased head length. This might have resulted due to selection pressure in this experimental variety towards increased head length. At Sadore, it was also observed that the seed multiplication during rainy season 1982 (without perfect isolation) and during dry-season 1982-83 (with perfect isolation) resulted into significant increase in head length for experimental variety ITMV 8001. The results were similar to

Table 1. Performance of the pearl millet populations raised from different seed lots

Population	Seed lot	Days to 50% flowering			Plant height (cm)			Head length (cm)			Grain yield (kg/ha)		
		M	S	A	M	S	A	M	S	A	M	S	A
ITMV 8001	R 81	68	66	67	245	273	259	50	59	54	1130	780	955
ITMV 8001	R 82	67	63	65	247	253	250	60	62	61	1092	846	969
ITMV 8001	D 82-83	68	71	69	242	275	258	65	69	67	1007	698	852
ITMV 8003	R 81	68	63	65	228	231	229	51	41	46	998	990	994
ITMV 8003	R 82	67	67	67	233	235	234	51	52	51	989	793	891
ITMV 8003	D 82-83	68	68	68	234	249	241	59	49	54	964	921	942
ITMV 8004	R 81	64	60	62	237	242	239	50	52	51	918	927	922
ITMV 8004	R 82	66	60	63	213	225	219	48	53	50	883	992	937
ITMV 8004	D 82-83	64	62	63	220	224	222	47	54	50	840	788	814
Comp. (Souna Mali x Ankutess)	R 81	62	63	62	210	232	221	36	38	37	1077	837	957
Comp. (Souna Mali x Ankutess)	R 82	66	61	63	236	250	243	35	41	38	1058	792	925
Comp. (Souna Mali x Ankutess)	D 82-83	64	61	62	208	248	228	33	42	37	1093	726	909
Mean x		66	64	65	229	245	237	49	51	50	1004	840	922
L.S.D.		1	1	1	5	8	7	5	6	4	136	108	104
C.V. %		3	5	3	9	10	7	15	17	10	17	15	11

M = Maradi, S = Sadore, A = Average of 2 locations

R = Seed produced in rainy season (crop season)

D = Seed produced in dry-season (off-season)

those obtained at Maradi as well as when averaged over the two locations. This variety has been developed from the INMG-1 (Singh and Naino, 1988) which is a genepool of long headed genotypes of African origin. Preference for longer ear heads form the general practice in seed multiplication of this variety. The differences in head length due to time and method of seed production was nonsignificant for all other experimental varieties and composites where no selection pressure was applied for this trait during the seed multiplication.

The influence of time of seed production was also statistically nonsignificant on grain yield. Numerically, the crop raised from rainy season seed lots produced better grain yield than from dry season for all the pearl millet populations.

The results of present studies revealed that when several pearl millet populations are to be multiplied at the same time, the seed production of these experimental varieties and composites can be undertaken even in absence of recommended isolation, by planting them during the rainy season (regular cropping season) in large plots ($> 2500\text{m}^2$), in square plots discarding the border rows (6-8 m on all 4 sides) followed by grided mass selection by sampling alternate hills in the central rows. This system not only maintains desirable mean performance in the population with much ease but reduces losses caused by unfavourable and unnatural environment in which the crop is grown during the off-season. The seed production in large plots without perfect isolation can be undertaken by the breeder if the seed of several experimental varieties, synthetics and composites are to be maintained at one site where recommended isolations (1 km distance from other variety) are not possible during the main cropping season. Slight contamination due to undesirable pollen and gene flow from adjacent plots can be reduced by planting varieties with distinct maturity cycles separated by several hills of border rows.

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Short Communication

**SALTBUSH : ITS PERFORMANCE AND POTENTIAL
IN THE INDIAN ARID REGION**

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Saltbushes (*Atriplex* spp.), family Chenopodiaceae, occur widely in the arid and semi-arid regions of the world, particularly in the southern rangelands of Australia and north America. They are perennial, evergreen, fodder shrubs, and are reported to grow in saline soils even with only 50 mm rain water (Francelet and Le Houerou, 1971). Some frost resistant species thrive under low temperatures of -10° C to 15° C, while *A. confertifolia*, is photosynthetically active from 5° to 50° C. This is the widest range of temperature adaptability known for any plant (Caldwell, 1972). They are excellent colonizers of newly disturbed areas (Mc Arthur *et al.*, 1983). All saltbushes from Australia are C4, whereas other areas have both C3 and C4 species (Osmund *et al.*, 1980). Saltbushes exhibit ecotypic adaptations, genetic variability and physiological drought resistance capability. Introduction of these species in the arid regions of the country is of paramount importance for enhancing fodder production.

The seeds of the three species namely, *A. nummularia* (EC 129766), *A. halimus* (EC 129767) and *A. canescens* (EC 129768) introduced from Tunisia in 1979 were sown in pots. The seedlings, 15-20 cm in height, were transplanted in furrows at a spacing of 2 m at the experimental farm of the Regional Station of National Bureau of Plant Genetic Resources at Jodhpur. Irrigation @ 1 litre water per plant at the time of transplanting followed by 2 litres for 20 days was applied. Afterwards, no regular irrigation was given and the plants received only rain water.

Five year old plants were harvested above ground level and observations were recorded for number of branches, length of branches, number of leaves per plant, and fresh and dry weights of branches and leaves. Since the branches exhibited wide variations in length, three arbitrary categories were made to ease the analysis and interpretation of data i.e. <50 cm, 50-75 cm and > 75 cm in length.

Out of the three species transplanted, *A. canescens* and *A. halimus* revealed 85 per cent and 50 per cent survival in the field compared to only 30 per cent of *A. nummularia*. High temperatures (39-41° C) alongwith meagre rainfall (8-16 mm) for two months after transplantation resulted in their poor survival.

Growth studies revealed that *A. halimus* and *A. canescens* were drooping types, while *A. nummularia* was erect growing. Five years old plants of *A. nummularia* were the tallest with a height of 1.5 m followed by *A. halimus* (0.9 m) and *A. canescens* (0.8 m). The leaves of these three species were semi-succulent and flattened. The maximum deposition of salt on leaf surfaces was observed in *A. nummularia* followed by *A. halimus* and *A. canescens*. In *A. nummularia*, the leaves are bluish grey, broad, oval and almost circular. *A. halimus* also bears

circular leaves with serrated margins but are smoother than *A. nummularia*. In *A. canescens*, the leaves are smooth, narrow with entire margins. The plant canopy ranged from 0.75 m to 1 m in these species (Plate I).

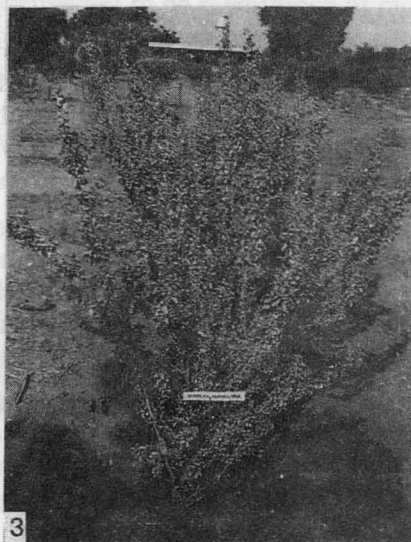
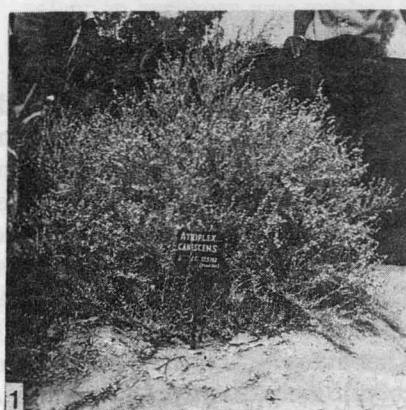


Plate I. Three introduced *Atriplex* species

1. *A. canescens*, 2. *A. halimus* and 3. *A. nummularia*.

Variation in the branch number (30 to 90 branches/plant) was noted in all the three species. Length of branches also varied from 12-125 cm. The number and proportion of long branches in *A. nummularia* were more than *A. canescens* and *A. halimus*. The fresh weight of the above ground plant parts per plant was the maximum in *A. nummularia* (658 g) followed by *A. halimus* (608 g) and *A. canescens* (538 g). Higher contribution of leaves (61%) to biomass in *A. nummularia* was observed compared to *A. canescens* (59%) and *A. halimus* (42%). Flowering was profuse in all the three species. However, the seed setting in *A. nummularia* was poor. Success in propagation by cuttings had also been achieved at this station. Seeds may be harvested from second season onwards. Properly dried seeds stored under dry conditions in tin or plastic bags retained their viability for about 3 years after which germination gradually declined.

Of the 300 *Atriplex* species known, about 50 are considered as fodder shrubs, of which, 10 are actually cultivated, viz, *A. atacemensis*, *A. canescens*, *A. glauca*, *A. halimus*, *A. lentiformis*, *A. nummularia*, *A. repanda*, *A. rhagodiodes*, *A. semibaccata* and *A. vesicaria*. They are known to produce large amounts (about 7590 - 10169 kg ha⁻¹) of herbage even under minimal cultural treatments (Goodin and Mc Kell, 1971). Out of the three species observed, *A. nummularia* produced maximum biomass as compared to *A. halimus* and *A. canescens*. Also, the contribution of leaves to biomass was found greater in the former. Yields of high edible matter in *A. nummularia* had also been reported (Watson *et al.*, 1987). Mean yield of 10.37 tonnes ha⁻¹ of green mass and 2.91 tonnes ha⁻¹ of dry mass per year was reported in *A. nummularia* (De Cock, 1980). Grazing experiments on sheep indicated that about two-third of the year's biomass was available as browse from the second season of plant establishment (De Cock, 1980). Ruminants require about 7% protein in their diets for rumen microorganism to effectively digest and metabolise carbohydrates and fats. The protein content in various *Atriplex* spp. ranges from 5.3 - 19.3% (Welch and Monsen, 1981). Also due to adequate digestibility, livestock feeding on salt-bushes seldom loose weight. The mean values of analyses of various plant parts from several locations suggested higher protein percentage and nutrient status of *A. nummularia*, *A. halimus* and in *A. canescens* (Le Houerou, 1980).

Thus, the higher biomass together with high nutritive value render *A. nummularia* a better status as a fodder species in comparison to *A. canescens* and *A. halimus*. The wide adaptability of *Atriplex* to xericity and salinity, its high fodder production potential and rapid propagation by seeds and cuttings does offer a great scope for the cultivation of this plant in the Indian desert, particularly in the wastelands and saline areas. Attempts are to be made to seed them in mixes with grasses as natural supplement to improve the nutritional value of fodder. However, mass scale trials with different species at various sites ascertain the adaptive strategies and suitability at species level.

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Short Communication

**EVALUATION OF SUGARCANE CLONES UNDER COASTAL
CONDITIONS OF ANDHRA PRADESH**

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Two varieties, Co 6907 (early) and Co 7219 (mid-late) occupy major area under sugarcane in Andhra Pradesh, particularly the coastal region. Co 6907 is a non-flowering type under natural conditions and hence cannot be utilised in hybridisation programmes, thus limiting the number of local varieties available for crossing. To identify some promising early and mid-late types for future use in crossing programmes, 50 canes mostly 1983 'Co' series alongwith three standards, namely, Co 6304, Co 7219 and Co 6907 were evaluated in a randomised block design with two replications. The clones were planted in two row plots of 6m length spaced 80cm apart. Twenty five three-budded setts were planted at equal distance in each row. At 10 month crop stage, sample juice analysis was carried out to identify the elite clones in comparison with the early standard Co 6907. The trial was harvested at 12 month crop stage and data on various cane yield and juice quality parameters were recorded.

The analysis of variance showed significant differences among genotypes for all the traits, except purity percentage, indicating the potentiality of the material for isolating parents which may produce better progenies. The maximum genetic variance was observed for the number of millable canes (NMC) followed by the cane yield and the cane length. The observed high variability amongst the clones could be due to different genetic constitution of the genotypes in respect to these characters. In general, variance for quality traits was low.

Between the mid-late standards, Co 6304 was the better variety for sugar yield per plot (16.91 kg) at 12 months; Co 8345, Co 8349, Co 8350, Co 8356 and Co 8369 were significantly superior to it. In comparison with the local mid-late check, Co 7219, Co 7606, Co 7643, Co 7901, Co 8344, Co 8345, Co 8346, Co 8349, Co 8350, Co 8356, Co 8361, Co 8363, Co 8364, Co 8366, Co 8367, Co 8369, Co 85035, Co 85036 and Co 85044 yielded significantly higher sugar yield per plot. The performance of Co 8014, Co 8343, Co 8347, Co 8351, Co 8352, Co 8357, Co 8359, Co 8365, Co 85041 and Co 86047 was similar to the standard variety Co 7219. Further, Co 8347 and Co 8351 for germination per cent; Co 7643, Co 7901, Co 8345, Co 8346 and Co 85033 for NMC; Co 8365 and Co 8366 for cane length; Co 8365 and Co 8369 for single cane weight and Co 8345 for cane yield were significantly superior to the respective best standards.

The early variety Co 6907 was included to compare the sucrose percentage in juice and to identify promising clones which accumulated sucrose at par with this

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Table 1. Mean performance of promising flowering clones under coastal conditions of Andhra Pradesh

Genotype	Germination %	NMC	Cane diameter (cm)	Cane length (cm)	Single cane weight (kg)	Sucrose (%)		Purity (%)	CCS (%)	Cane yield (kg)	CCS/plot (kg)	Flow-ering time	Pollen fertility (%)
						10th month	12th month						
Co 7643	49.67	151*	2.20	261	0.80	18.16	19.16	87.75	13.37	120.75	16.16	IV, OCT	87.4
Co 7901	52.67	189*	2.10	233	0.58	16.18	20.22	90.22	14.12	109.40	15.47	III, Nov	45.0
Co 7907	60.99	141	2.30	264	0.82	17.59	18.39	87.91	12.68	115.25	14.63	I, Nov	45.0
Co 8021	64.34	133	2.20	282	0.88	19.07	19.99	87.99	13.77	117.15	16.10	IV, Nov	25.0
Co 8342	61.34	145	2.70	286	1.16	19.34	19.36	91.48	13.61	116.20	22.53*	I, DEC	65.0
Co 8345	64.67	164*	2.55	269	0.98	15.80	19.05	89.57	13.41	160.50*	21.52*	III, Nov	81.0
Co 8346	61.33	147*	2.55	281	0.94	17.12	18.72	89.30	13.01	137.70	17.92	IV, Nov	5.0
Co 8347	82.00*	132	2.50	254	0.96	17.29	17.16	88.84	11.90	126.60	15.05	I, Nov	51.0
Co 8351	80.00*	99	2.90	245	1.08	17.47	19.89	86.82	13.64	106.90	14.58	III, NOV	16.0
Co 8357	46.34	87	2.75	278	1.16	17.24	19.57	88.92	13.57	100.55	13.66	II, NOV	0.0
Co 8361	43.99	126	2.50	283	1.06	15.70	20.27	90.64	13.69	133.50	18.28	IV, Nov	44.0
Co 8365	28.00	63	3.05	324*	1.50*	15.78	20.24	87.73	13.84	92.80	12.84	II, Nov	66.0
Co 8368	49.34	115	2.60	318*	1.26	17.23	20.07	89.21	13.53	143.30	19.37	II, Nov	0.0
Co 8368	29.67	102	2.65	290	1.14	19.86	20.50	90.27	14.36	114.55	16.42	IV, Nov	11.0
Co 8369	38.67	103	3.00	299	1.46*	16.90	19.04	87.71	13.49	148.90	20.08*	IV, Nov	7.0
Co 85033	45.34	168*	2.20	227	0.82	19.08	20.04	89.49	13.95	137.85	19.17	III, Nov	7.0
Co 85041	44.67	114	2.30	270	0.84	17.98	18.96	86.93	13.01	95.80	12.46	I, Nov	0.0
Co 86047	42.00	98	3.00	287	0.96	18.96	20.01	89.29	13.91	94.10	13.09	II, Nov	33.0
Standards													
Co 6304 (ML)	41.00	126	2.95	1.04	18.84	18.76	86.92	12.88	131.00	16.91	II, Nov	9.6	
Co 7219 (ML)	51.00	108	2.35	266	0.84	18.43	19.58	88.35	13.54	90.70	12.27	II, Nov	32.6
Co 6907 (E)	60.33	131	2.30	232	0.76	19.58	19.83	89.72	13.81	99.90	13.88	Non-flowering	-
C.D (5%)	18.83	15.66	0.35	43.11	0.23	1.73	1.15	NS	0.99	20.66	2.97		

* Significant at P=0.05

+ Observations recorded at Coimbatore (Main Campus) during 1988.

I, II, III, IV - Four weeks of month

local check. The clones, Co 8021, Co 8025, Co 8342, Co 8350, Co 8356, Co 8358, Co 8362, Co 8368, Co 85033 and Co 85268 were found promising for sucrose percentage at 10 month crop stage in comparison with the early check. Since all the clones evaluated did not flower at Coimbatore and non-flowering clones could not be utilised in future breeding programmes, therefore, performance of only some elite flowering clones is presented in Table 1. Some of the clones could serve as genetic stocks which may contribute to sugarcane improvement in east coast zone.

Short Communication

**VARIABILITY IN YIELD AND QUALITY CHARACTERS
IN TARO (*Colocasia esculenta*)**

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Taro (*Colocasia esculenta*) is widely cultivated in the tropics either as a tuber vegetable or as a staple food. The tubers are a good source of starch. The leaves and petioles are used as leafy vegetable, though some types are not used as leafy vegetable because of high acidity caused by Calcium oxalate and glycosides. In India, taro (*C. esculenta*) is popular all over and much variability exists in its forms. At the NBPGR Regional station at Vellanikkara, Trichur (Kerala), 808 samples of cultivated and wild forms of taro were assembled from all over the country. Out of these, 467 accessions were characterised and 57 morphotypes (treated as M1 to M57) were identified (Anon. 1989). These 57 morphotypes comprised 4 distinct groups viz. *C. esculenta* var. *antiquorum* (30), *C. esculenta* var. *esculenta* (13), wild stoloniferous (7) and semi stoloniferous (7). These morphotypes were evaluated for taste, acidity and oxalic acid content.

Quality traits were studied adopting standard procedures. Equal slices of tubers and sections of young petioles and leaves of each representative morphotype were kept in boiling water for 20 minutes, cooled and analysed for acidity and oxalic acid (%). Taste of tuber was marked on 0-9 scale and acidity of tuber leaf and petiole were graded as low, medium and high. Oxalic acid content of tuber flesh was estimated based on the analytical methodology for tuber crops adopted by Central Tuber Crops Research Institute, Trivandrum (Unnikrishnan *et al.*, 1987).

Wide variation in all the characters were observed (Table 1). In the *antiquorum* group, M7, M8 and M27 were better in taste and low in oxalic acid content. Their tubers were not acrid but leaves and petioles were moderately to highly acrid indicating unsuitability for use as green leafy vegetable. M 47 with no acidity in tuber and leaf petiole and low acidity in leaf, appeared to be better. In general, Oxalic acid content was higher in accessions from North-Eastern states. In productivity, M3 (2.45 Kg fresh tuber weight/3 plants) and M7 (2.3 Kg/3 plants) appeared superior.

Among the *esculenta* forms, M20, M 22 and M 29 having very good taste scored over others. M 20 with low oxalic acid and acidity in tuber and leaf and moderate acidity in petiole, was preferable. M 46 and M 50 having good taste and no acidity in tuber and petiole, low or no acidity in leaf and moderate yield, appeared promising.

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Table 1. Variability in yield and quality traits in different morphotypes of taro

Morpho- type	Distribution	Tuber taste (1-9 Scale)	Oxalic acid (%)	Acridity of			Status	Yield of 3 plants (Kg)
				tuber	leaf	petiole		
A. Antiquorum types								
1	All over	2	0.170	L	M	M	Cultivar	0.68
2	All over	7	0.035	L	M	M	"	0.82
3	Kerala & Tamil Nadu	5	0.913	A	H	H	"	2.45
4	Himachal Pradesh (North Western Region)	6	0.308	A	M	L	"	1.18
5	North Western Region	6	0.283	L	M	M	"	0.75
6	North Western Region	6	0.164	A	M	M	"	0.50
7	Bihar	8	0.197	A	M	M	"	2.43
8	Kerala, Maharashtra North Eastern Region	8	0.170	A	H	H	"	0.93
9	Kerala & Tamil Nadu	7	0.182	A	H	H	"	0.99
10	Karnataka	3	0.134	H	H	H	"	0.83
12	Kerala & Karnataka	2	0.151	H	H	H	"	0.59
13	Kerala	7	0.182	A	H	H	"	1.10
14	Maharashtra	-	0.063	-	M	M	"	0.90
16	Kerala	2	0.126	M	M	M	Wild type	0.57
27	Kerala, Karnataka	8	0.113	A	H	M	Cultivar	1.08
31	Unknown	7	0.139	L	L	M	"	2.15
37	Kerala	3	-	M	L	L	"	0.30
39	North Eastern Region	7	0.195	A	M	M	"	0.48
40	North Eastern Region	7	0.372	A	M	M	"	1.44
41	North Eastern Region	6	0.687	A	M	M	"	1.60
42	North Eastern Region	1	0.422	L	M	M	"	2.00
43	North Eastern Region	-	0.523	-	L	M	"	1.20
44	North Eastern Region	7	0.378	A	M	L	"	0.65
45	North Eastern Region	6	0.687	A	M	M	"	1.10
47	North Eastern Region	7	0.504	A	L	A	"	1.30
48	North Eastern Region	7	0.832	A	M	L	"	1.70
51	North Eastern Region	7	0.340	A	M	L	"	1.05
53	North Eastern Region	4	0.347	A	M	A	"	0.30
54	North Eastern Region	4	0.536	A	H	M	"	1.65
56	Karnataka	-	0.151	-	M	M	Wild type	0.45

Contd....

Table 1. Contd....

Morpho- type	Distribution	Tuber taste (1-9 Scale)	Oxalic acid (%)	Acridity of			Status	Yield of 3 plants (Kg)
				tuber	leaf	Petiole		
B. <i>Esculenta</i> types								
18	Kerala	4	0.107	L	M	A	Cultivar	1.56
19	Kerala	7	0.271	A	L	M	"	1.51
20	Kerala, Karnataka, Tamilnadu	8	0.113	A	L	M	"	1.10
21	Kerala, Himachal Pradesh	7	0.063	A	L	L	"	0.43
22	Kerala	9	0.145	A	H	M	"	0.42
24	Kerala	6	0.095	A	L	L	"	0.71
26	Kerala	1	0.126	A	H	M	"	0.67
29	Karnataka	8	0.088	A	H	M	Wild type	0.65
32	Kerala	7	0.882	A	M	H	"	1.80
38	North Eastern Region	5	0.567	A	L	L	Cultivar	0.60
46	Karnataka	7	-	A	A	A	"	1.62
50	North Eastern Region	6	0.214	A	L	A	"	1.90
52	North Eastern Region	4	0.347	A	M	A	"	0.80
C. <i>Stoloniferous</i> types								
17	Kerala, Tamil Nadu	4	6.258	A	M	M	Wild type	0.41
23	Karnataka	8	0.126	A	H	M	"	0.56
28	Kerala	-	0.126	-	M	M	"	0.35
30	Karnataka	7	0.268	A	M	H	"	0.30
34	Tamil Nadu	-	0.435	-	M	L	"	0.20
35	Kerala	-	0.441	-	H	H	"	0.80
57	Karnataka	-	0.126	-	H	L	"	2.25
D. <i>Semi-stoloniferous</i> types								
11	Kerala, Tamil Nadu	7	0.459	A	H	H	"	0.43
15	Karnataka, Tamil Nadu	1	0.207	M	H	H	"	0.94
25	Karnataka	3	0.113	M	H	L	"	0.20
33	Karnataka	7	0.139	L	L	M	"	0.40
36	Tamil Nadu	7	0.233	A	M	M	"	0.29
49	North Eastern Region	5	0.252	M	L	M	"	2.70
55	Karnataka	-	0.189	-	H	L	"	0.33

A = Absent, L = Low, M = Medium, H = High

Taste scored on 1-9 scale, where, 1-3 = Low, 4-6 = Medium and 7-9 = High

The wild stoloniferous group comprised accessions with low to medium oxalic acid content and medium to high acidity of leaf and petiole. M 57 with low oxalic acid content, low acidity in petiole and high tuber yield (2.25 Kg/3 plants) was observed promising.

The semi-stoloniferous group containing all wild morphotypes varied from poor to moderately good in tuber taste, low to moderately high in oxalic acid content and acidity of the tuber, low to high for acidity of the leaf and petiole. M49 having moderately good taste, low oxalic acid content, moderate acidity in tuber and petiole and low acidity in leaf yielded 2.7 Kg/3 plants and appeared promising. The frequency class distribution (Fig. 1) showed that acidity in cooked leaf and petiole had almost normal distribution, whereas, yield, taste and acidity of tuber showed abnormal distribution which suggested differential selection pressure for different characters. The above observations are of interest because, contrary to the expectations, wild forms showed considerable variability in all the characters observed. Thus, forms with good yield, taste and low acidity in cooked tuber, leaf and petiole were found even among the wild stoloniferous and semi stoloniferous groups. The results indicated wide polymorphism in the species for the characters studied.

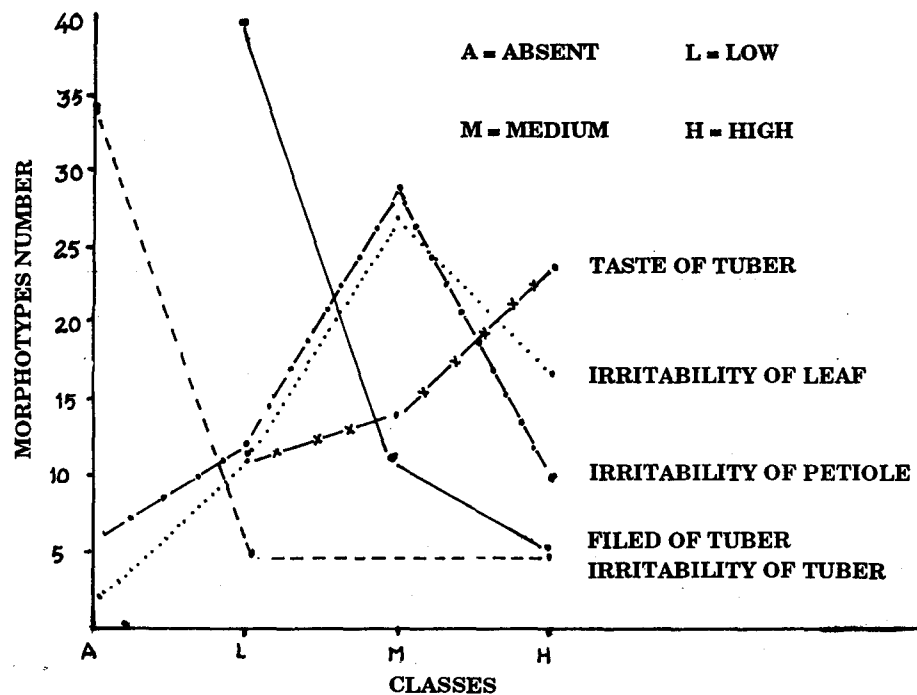


Fig. 1. Showing frequency classes of edibility parameters of taro

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Short Communication

GENETIC RESOURCES OF SILK PRODUCING NON-MULBERRY PLANTS

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India grows all known commercial varieties of silk viz. mulberry, tasar, muga and eri. The tasar, muga and eri come under the non-mulberry sector and contribute a lot in the national economy. The three commercial non-mulberry silkworms are polyphagous and feed on the leaves of many plants. Recognising the importance of natural resources and their future utilisation in genetic improvement, various agencies are collecting germplasm. Due to devastating deforestation, the useful genetic resources of non mulberry food plants are being depleted very fast. If the timely efforts are not made, some of the most useful plants will be extinct in near future. In view of above facts, it is necessary to undertake genetic resource survey (exploration/collection), conservation and evaluation of food plants of tasar, eri and muga silkworms in India for protection as well as utilisation of valuable genes with a view to bring about further improvement in these food plants.

NON-MULBERRY SILK YIELDING FOOD PLANTS

Tasar food plants

Tropical tasar insect *Antheraea mylitta* D. primarily feeds on *Terminalia tomentosa*, *T. arjuna* and *Shorea robusta* and secondarily on *Lagerstroemia parviflora*, *L. indica*, *Zizyphus jujuba*, *Syzygium cumini*, *Bauhinia variegata*, *Careya arborea*, *Tectona grandis*, *Bombax malabaricum*, *Madhuca indica* and *Anogeissus latifolia*. Genus *Terminalia* may rightly be called as the backbone of tasar industry as almost 90 per cent production of tasar silk depends on *T. arjuna* and *T. tomentosa* trees. This genus comprises 100 species widely distributed in the tropical and sub-tropical regions of the world. More than a dozen species of *Terminalia* occur in India. While all efforts to utilise *T. paniculata*, *T. chebula* and *T. belerica* in Bihar, Madhya Pradesh, West Bengal, Orissa and Maharashtra as secondary food plants of *A. mylitta* D. have not met with much success, tribals of Andhra Pradesh, Karnataka and Kerala have successfully reared on these three species especially on *T. paniculata*. Several other indigenous species of *Terminalia*, viz., *T. muelliariana*, *T. glabra*, *T. mucronata*, *T. pyrifolia* and *T. foetidissima* still await their evaluation for tasar culture. Besides, *T. procera* and *T. manii* are also found in India along with *T. bialata* and *T. catappa* in the forests of Andaman and Nicobar islands. While *T. citrina* and *T. myriocarpa* are distributed in foot hills of Himalayas from north Bengal eastwards to Assam, Khasi hills and Arunachal Pradesh, *T. pallida* extensively occurs in South India.

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T. arjuna and *T. tomentosa* exhibit distinct variation in nature and show occurrence of natural hybrids between different species/sub-species, varieties or ecotypes (Hooker, 1878; Hains, 1961; Bahadur and Gaur, 1980). *T. tomentosa* has been divided into three taxonomical varieties, viz., *typica* (*alata*), *crenulata* and *coriacea* (Hooker, 1878; Bahadur and Gaur, 1980). Likewise *T. arjuna* also has two varieties, viz., *arjuna* and *angustifolia* (Hooker, 1878). In *T. tomentosa* and *T. arjuna*, variations occur in nature for bark colour, leaves and fruits. Variations occur in bark (grey, dark-grey or black), leaves (hairy or non-hairy with thin or thick texture) and shape of the leaves (elongate, oblong, cordate, obovate, elliptic etc.). Present investigations revealed that there are more than 25 biotypes of both taxa which can be isolated and maintained separately. Non-hairy *T. tomentosa* are nutritionally more rich than hairy forms (Sinha *et al.*, 1989). Further, *T. arjuna* and *T. tomentosa* can also be distinguished on the basis of number of wings (3-12) in fruits (Srivastav & Priya Ranjan, 1988).

The temperate *tasar* food plants include various species of *Quercus*, viz., *Q. serrata* (syn. *Q. acutissima*), *Q. semicarpifolia*, *Q. incana*, *Q. dealbata*, *Q. himalayana*, *Q. ilex* and *Q. lanigenosa* which occur at elevation of 900-2400 m. The rearing performance of these taxa not only differs at various altitudes but also in eastern and western sub-Himalayan belts. *Q. incana* and *Q. himalayana* give better performance in western sub-Himalayan belt while *Q. serrata* gives the best results in eastern zone. Further, *Q. semicarpifolia* has ensured second crop rearing of *A. prylei* in Himachal Pradesh where it occurs as climax species above 2100 m elevation.

Muga food plants

The primary food plants of *muga* silkworm are *Machilus bombycina*, *M. odoratissima* and *Litsaea polyantha*. There are more than 16 biotypes of *M. bombycina* in nature. Depending upon the leaf shape and size, four varieties have been identified in *Machilus bombycina*. They are *naharpatia* (leaves resemble with nahar tree), *ampatia* (leaves resemble with mango tree), *jampatia* (leaves resemble with jamun tree) and *kathalpatia* (leaves resemble with jackfruit tree). The variety *naharpatia* has been considered as the best variety for cultivation of *muga* silkworm. Rearers recognize two varieties of *Machilus bombycina*, sweet and bitter or sour, on the basis of leaf taste, out of which sweet variety gives better rearing results. Similarly, two varieties have been identified in *Litsaea polyantha* on the basis of leaf shape, size and texture. The oblong variety is characterised by oblong, narrow and thin leaves while ovate variety is identified by its oval, broad and thick leaves. The ovate variety is preferred by *muga* silkworm.

The other food plants which are used less frequently for rearing could be considered of secondary importance include *Litsaea citrata*, *L. salicifolia*, *L. nitida*, *Actinodaphne obovata*, *A. angustifolia*, *Zanthoxylum rhesta*, *Celastrus monosperma*, *Magnolia sphenocarpa* and *Zizyphus jujuba*. The *muga* silkworms reared on *L. citrata* yield white silk instead of golden yellow.

As is obvious, *Litsaea* and *Machilus* genera seem to be of prime importance for *muga* culture, every attempts should be made to enrich the germplasm of *Litsaea*.

Eri food plants

Ricinus communis, *Heteropanax fragrans*, *Evodia flaxinifolia*, *Manihot utilissima*, *Plumeria acutifolia*, *Jatropha curcas*, *Ailanthus glandulosa*, *Sapium ellgeniaefolium*, *Zanthoxylum rhesta*, *Hodgsonia heteroclita*, and *Carica papaya* are the most important species used as food plants of *eri* silkworm. Castor (*Ricinus communis*), keseru (*Heteropanax fragrans*), payam (*Evodia flaxinifolia*) and tapioca (*Manihot utilissima*) are important in the order of choice of food plants. Castor is considered the best food plant as *eri* silkworms reared throughout on castor leaves, yield large size cocoons, rich in silk content. Although improved varieties of castor exist in India for oil seed production, 'high leaf yielding' varieties from sericulture point of view are meagre. Usually the red variety is preferred by rearers but the choice is probably due to its red colour which is more aesthetic in appearance than the green variety. The green castor plant is delicate and cannot stand adverse weather. The castor is available in both annual and perennial types. The perennial green variety is preferred by some rearers due to the quality, quantity and duration of the leaves. The perennial variety lasts 3 to 4 years, branches profusely and grows almost like a tree yielding abundance of seeds and leaves.

The Germplasm collection of mulberry food plants should have many species/sub-species/varieties belonging to genera such as *Terminalia*, *Shorea*, *Quercus*, *Litsaea*, *Machilus*, *Ricinus* and *Heteropanax* and their germplasm should be maintained in the field in regions environmentally suitable for them. As most of the production of tasar, oak tasar, muga and *eri* silk comes from Bihar, Madhya Pradesh, Manipur, Himachal Pradesh and Assam, the genepools of *Terminalia*, *Shorea*, *Quercus*, *Litsaea*, *Machilus*, *Ricinus* and *Heteropanax* may be established at some suitable centres in Madhya Pradesh, Bihar, Himachal Pradesh and Assam.

All the non-mulberry plants being forest taxa, exhibit wide area of distribution. For exploration of various species of *Shorea* and *Terminalia*, Madhya Pradesh, Bihar, Orissa, Maharashtra and West Bengal states should be given prime importance as these states possess good variability in these genera. Besides, Garhwal and Kumaon regions of Himalaya need to be explored for *Terminalia* which exhibits striking variability and remain unexplored from tasar cultivation point of view. Several other species of *Terminalia*, viz., *T. manii*, *T. catappa*, *T. pallida*, *T. procera*, *T. bialata*, *T. muelliariana*, *T. glabra*, *T. mucronata*, *T. pyrifolia*, and *T. foetidissima* still await their survey from north-eastern region; foot hills of Himalayas to north Bengal eastwards to Assam, Khasi hills, Arunachal Pradesh and Andaman and Nicobar islands. The exploration of *Quercus* species may be conducted in whole of north-west to north eastern Himalayan belts. *Machilus* and *Litsaea* are also distributed in western and eastern Himalayan belt. While species of eastern Himalayas have been exploited for commercial purposes, the varieties of western Himalayas are yet to be utilised for *muga* silk production. Hence exploration of both the species should be done throughout the sub-Himalayan belt.

More than a dozen species of *Terminalia* occur in Sri Lanka, India, Myanmar, Cambodia, Vietnam with the extended distribution in Indonesia, Malaysia, New

Guinea and Australia. No attempt has practically been made to introduce exotic germplasm from above countries except from USA and Central America. Attempts are required to be made to enrich the collection by introducing *Quereus*, *Machilus*, *Litsaea* and castor cultivars from other countries. •

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Short Communication

**THE COMPOSITION AND CHARACTERISTICS OF SEED
OIL OF *Celastrus paniculatus* GERMPLASM**

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Jyotishmati (*Celastrus paniculatus*) is a large deciduous climber, occurring in sub-Himalayan tracts upto 2000 m in Central India, Western Ghats, Eastern Ghats, extending to Rajmahal hills in Bihar and Orissa upto 1500 m elevation. This hardy species attains plant height upto 18 m in mountain tracts and crevices of rocks and along the bridle paths in the deciduous forests. Its fruit is globular in shape, containing 3 to 6 seeds, enclosed in an orange red aril. The seed and seed-oil are stimulant, nervine tonic and sharpen memory and therefore, is widely used in medicine (Nadkarni, 1976). Germplasm collection from the hills of Uttar Pradesh was made for identification of superior genotypes in yield and physiologically active terpenic alkaloids, mainly 'celapanin' and 'celapanigin' (Wagner et al., 1974). Its cultivation is expected to meet increasing demand of the seed oil in pharmaceutical industry.

Seeds were collected from wild populations at different altitudes in the northern hills of Garhwal district in Uttar Pradesh and compared with market samples from Delhi and Indore originating from N.E. Andhra Pradesh and Central India respectively. Fixed oil was extracted from ground seed. This involved continuous hot extraction with petroleum ether (40-60°) in a soxhlet apparatus for 16 hours. The extraction was initially carried out for 8 hours, then the seeds were taken out, dried, again powdered and run for extraction in petroleum ether for next 8 hours. This procedure gave optimum recovery of oil. Physiologically active alkaloids (Wagner *et al.*, 1974) were estimated in the seed as total alkaloids following general method for estimation of alkaloids (Higuchi and Bodin, 1961). Qualitative characters of the oil were analysed by standard pharmacopoeial method (Anon., 1966).

An analysis of the five accessions collected from different altitudes in U.P. hills and three samples procured from market showed that seed contained approximately 50 per cent (W/W) highly coloured, faintly aromatic, thick and optically active oil (Table 1). Delhi market sample, on analysis gave 0.1815 per cent total alkaloids in the seed. Of this, 0.1634 per cent was estimated in the oil and 0.0098 per cent was found in the defatted seed. It was, thus observed that the alkaloids got extracted alongwith the oil. However percentage of total alkaloids in the seed of wild populations varied from 0.0100 per cent to 0.0580 per cent. The market samples collected from Vindhyan ranges (Indore) of Central India and parts of North-eastern Andhra Pradesh (referred as Delhi market samples) showed higher total alkaloid content ranging from 0.1008 per cent to 0.2709 per cent. In general, acid value of oil in the accessions from U.P. hills was lower than those of market samples except the samples from Sintali (U.P.) and Indore. The accessions from U.P. hills

Table 1. Chemical analysis of *Celastrus paniculatus* seeds collected from Tehri Garhwal (U.P. Hills)

Localities from were collected	Altitude (m)	Oil (W/W) (%)	Colour	Refractive index (27°C)	Sp. Gr. (27°C)	Specific rotation (5 % CHCl ₃ , (Sol.)	Acid value	Ester value	Saponification value	Total seed alkaloids (%)
<i>Wild populations</i>										
1. Rishikesh	580	50.55	TPR	1.4715	0.8380	+3°	17.74	266.70	284.49	0.0580
2. Sintali	660	46.17	TPR	1.4730	0.8414	+2°	33.56	233.89	287.35	0.0437
3. Dobata	750	53.63	TPR	1.4725	0.7958	+2°	14.40	277.75	292.15	0.0372
4. Takoli	900	53.85	TPR	1.4720	0.7451	+1°	18.24	262.00	280.24	0.0532
5. Saknidhar	1030	56.65	TPR	1.4700	.	+5°	22.52	291.95	314.47	0.0100
<i>Market samples</i>										
*1 Delhi-I	-	51.41	TPR	1.4705	0.8314	-	40.42	181.64	222.06	0.1815
*2 Delhi-II	-	48.20	TPR	1.4695	0.8768	-	51.93	165.53	217.46	0.1008
3. Indore	-	57.76	TPR	1.4710	0.8579	-	11.58	191.84	203.42	0.2709

TPR - Thick Pinkish Red

* Originated from N.E. Andhra Pradesh

possessed high ester and saponification values in their oil. Thus, the materials collected from the upper ranges of U.P. hills were at par in oil content but were found to be poor in total alkaloids content. High saponification values and unusually high acid values were observed as special characteristic of the seed oil and lower acids were earlier shown to be the constituent of esters other than glycerides (Sengupta & Bhargava, 1970). It is therefore, inferred that intensive survey for this species may be carried out in Vindhyan ranges of Central India and parts of North-eastern Andhra Pradesh in order to collect promising materials rich in physiologically active alkaloids.

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