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SEM STUDIES OF SEED COAT IN SOME ASIATIC VIGNA SPECIES AND THEIR TAXONOMIC AND PHYLOGENETIC SIGNIFICANCE

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Seed morphology, hilum structure and cellular structure of seed coat of predominantly cultivated and wild species of the genus Vigna in India were studied using scanning electron microscopy (SEM). The important species include mung bean (Vigna radiata (L.) Wilczek), urid bean (V. mungo (L.) Hepper), rice bean (V. umbellata (Thunb.) Ohwi and Ohashi), moth bean (V. aconitifolia (Jacq.) Marechal) and Pillipasera (V. trilobata Ait.) and their wild occurring closely related putative progenitor forms particularly V. radiata (L.) var. sublobata Verdc., V. mungo (L.) var. silvestris Lukoki, Marechal and Otoul, wild forms of V. umbellata and V. aconitifolia. Seed coat cellular structure and hilum were characteristic to each species and appeared to be species-specific. Considerable morphological similarities were observed between cultivated plants of V. radiata with its related wild species V. radiata var. sublobata, V. mungo with that of V. mungo var. silvestris and V. umbellata with its wild form. In V. aconitifolia, cultivated and wild types differed drastically in their seed coat surface pattern. SEM seed coat structure was found to be useful in establishing taxonomic and phylogenetic relationship in these Indian species of Vigna.

Seed coat morphology using scanning electron microscopy (SEM) have been used as taxonomic characters which may provide very useful and reliable evidence on phylogeny (Heywood, 1971; Brisson and Peterson 1976; Barthlott, 1981). The above investigators amply justified the utility of seed morphology and SEM seed coat surface structure in solving a variety of problems concerning systematics and evolution. Recent findings on scanning electron microscopy of seed coat surfaces showed this

to be a consistent and important source of character states at the species level (Canne, 1980; Wofford, 1981). SEM studies of seed coat cellular morphology were used in establishing species relationship among *Vigna-mungo-radiata-sublobata* and *silvestris* complex to provide evidences about the possible ancestors of the Indian domesticated species of *Vigna* (Chandel, 1980; Chandel *et al.*, 1984; Trivedi and Gupta, 1985, 1986). SEM seed coat morphology of *V. mungo*, *V. radiata* and their wild relatives were studied earlier as well (Sharma *et al.*, 1977, 1983). The wrong identification of *Vigna* species collected from Poona-Khandala and Mahablashwar regions of Western Ghats by the latter authors led to misinterpretation of SEM studies of seed coat patterns and further complicated the taxonomic and phylogenetic relationship in this complex. Trivedi and Gupta (1985, 1986) concluded that *V. mungo*, *V. sublobata* and *V. radiata* resemble each other in generally having reticulate seed coat pattern and it is therefore, difficult to separate them distinctly on this basis. Seed coat surface structure in *Vigna* possesses a strong heritable base (Rajendra *et al.*, 1979) in a cross combination involving *V. sinensis* with *V. sesquipedalis* where the single gene control for two types of macrosclereid traits was observed. The above findings support the genetic control of seed coat structure and thus this structure should be considered as a valuable heritable taxonomic character in the study of systematics and phylogenetic relationship. The present studies have been carried out to investigate the detailed SEM seed coat surface patterns of various cultivated species of *Vigna* and wild occurring related taxa collected from diverse natural habitats in the Indian Gene Centre. Taxonomic implications and relevance of SEM seed coat surface morphology in establishing phylogenetic relationship between cultivated and wild *Vigna* species have been elucidated.

MATERIALS AND METHODS

Specimens of several wild species of *Vigna* occurring in natural and disturbed habitats in India were collected from different ecological regions/microniches (Arora *et al.*, 1973; Arora, 1986; Chandel, 1984). Scanning electron microscopy of seed coat and hilum structure was undertaken involving different cultivated species and their close wild relatives (Table 1). The present investigations included cultivated species namely mung bean (*V. radiata* syn. *Phaseolus radiatus* (L.) Roxb.), urid bean (*V. mungo* syn. *Phaseolus mungo* L.), rice bean (*V. umbellata* syn. *Phaseolus calcaratus* Thunb.) and moth bean (*V. aconitifolia* syn. *P. aconitifolius* Jacq.), *V. trilobata* syn. *P. trilobus* Ait. The wild related taxa included in the present study are *V. radiata* var. *sublobata*, *V. mungo* var. *silvestris*, wild putative progenitor forms of rice bean (*V. umbellata*), and moth bean (*V. aconitifolia*).

Table 1. List of *Vigna* species/forms, their accession numbers and sources of collection.

S. No.	Name (Species)	Common name	Accession No.	Source
1.	<i>Vigna radiata</i> (L.) Wilczek	Mung bean (Cultivated)	Pusa Baisakhi	IARI, New Delhi.
2.	<i>V. radiata</i> (L.) var. <i>sublobata</i> (Roxb.) Verdc.	Wild progenator	PLX 274	Rishikesh, Utter Pradesh
3.	<i>V. mungo</i> (L.) Hepper	Urad bean (Cultivated)	NC55947	NBPGR, New Delhi.
4.	<i>V. mungo</i> (L.) var. <i>silvestris</i> Lukoki, Marechal and Otoul	Wild progenator	PLX 409	Khopli, Maharashtra.
5.	<i>V. mungo</i> (L.) var. <i>silvestris</i> Lukoki, Marechal and Otoul	Wild progenator	PLX 410	Khopli, Maharashtra.
6.	<i>V. umbellata</i> (Thunb.) Ohwi and Ohashi	Rice bean (Cultivated)	IC 18136	NBPGR, New Delhi.
7.	<i>V. umbellata</i> (Thunb.) Ohwi and Ohashi	Rice bean (Wild form)	IW 3176	Shimla Hills, Himachal Pradesh
8.	<i>V. aconitifolia</i> (Jacq.) Marechal	Moth bean (Cultivated)	PLMO 211	NBPGR, New Delhi
9.	<i>V. aconitifolia</i> (Jacq.) Marechal	Moth bean (Wild form)	C-2515	Rajendranagar, Andhra Pradesh
10.	<i>V. trilobata</i> Ait.	Phillipasera	IC 24830	NBPGR, New Delhi.

Seeds of these species were thoroughly cleaned and were dried at room temperature. Two or three well developed seeds of each species were mounted on brass stubs using silver paste with adhesive and were uniformly coated with a thin film of gold using ion sputter JEOL JFC-1100. The coated samples were examined at uniform tilt angle (45°) in scanning electron microscope model Jeol JSM-840A at an accelerating voltage of 20 kv and photographed. Surface structure of seed coat pattern was scanned uniformly around the hilum. The voucher specimens were deposited in the National Herbarium at NBPGRI, New Delhi.

RESULTS AND DISCUSSION

Vigna radiata and *V. radiata* var. *sublobata*

The seed shapes, hilum structures and seed coat cell patterns of *V. radiata* and its putative progenitor *V. radiata* var. *sublobata* exhibited considerable resemblance (Fig. 1-4). *V. radiata* possessed oblong, elongated, rectangular or wedge shaped seeds while in *V. radiata* var. *sublobata* was flattish, linear in shape and not raised. Surface structure in mung bean showed very elongated cells (5 to 6 times more in length than width), mostly rectangular or triangular in shape, arranged in parallel rows (Fig. 2). Wax deposition on the seed coat was observed to be very thick. External surfaces of waxy mounds on cell boundaries were quite irregular. Cell contours were distinct with varying thickness. Wax deposition in cell sutures was in the form of linear rows of globules. Due to distinct cell boundaries, uniform reticulum was formed on seed surface.

Seed coat surface structure and cellular details of *V. radiata* var. *sublobata* (PLX 274) showed significant variations in cell size (Fig. 4). In general, the seed surface was covered with a reticulum formed by cells varying from rectangular to ovate in shape. Cells were found to be elongated and were arranged side by side in wavy rows. Cell sutures were impregnated with wax forming mounds which were regular in outlines.

Vigna mungo and *V. mungo* var. *silvestris*

In *V. mungo*, seed shape was globular with roundish ends (Fig. 5), while in various wild accessions of *V. mungo* var. *silvestris*, shape of the seed varied from rectangular (Fig. 7) to oblong (Fig. 9). Structure of hilum was very distinct in urid bean and morphologically resembled the hilum in wild forms of *V. mungo* var. *silvestris*, being concave and deeply furrowed (Fig. 5, 7, 9). The hilum rim was very much raised and arilate and the suture was clearly marked while in PLX 409 where the hilum was not much raised and the suture was somewhat elongated rather than ovate. The seed coat in *V. mungo* was composed of hexagonal cells arranged in irregular rows forming a network on the seed

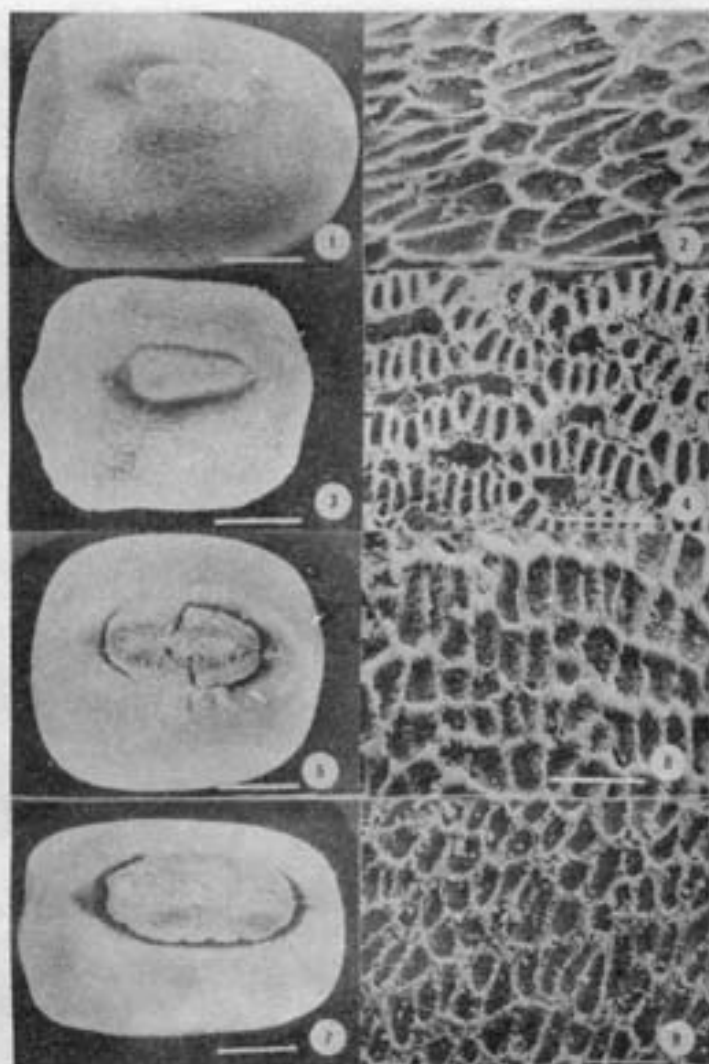


Fig. 1-8. SEM micrographs of seeds of *V. radiata*, *V. radiata* var. *sublobata*, *V. mungo* and *V. mungo* var. *silvestris*. Fig. 1. *V. radiata* wedge shape seed with linear hilum. Fig. 2. Seed coat pattern of *V. radiata*, rows of rectangular cells with wax deposition. Fig. 3. *V. radiata* var. *sublobata* (PLX 274) oblong seed with linear hilum. Fig. 4. Seed coat of PLX 274, showing rectangular cells arranged in wavy rows. Fig. 5. *V. mungo* globular seed with raised hilum. Fig. 6. Seed coat of *V. mungo* showing hexagonal cells arranged in network. Fig. 7. *V. mungo* var. *silvestris* (PLX 410) rectangular seed with hilum similar to *V. mungo*. Fig. 8. Seed coat pattern of PLX 410 showing almost hexagonal cells. (Fig. 1, 3, 5, 7-Scale Bar = 1 mm. Fig. 2, 4, 6, 8-Scale Bar = 100 μ m).

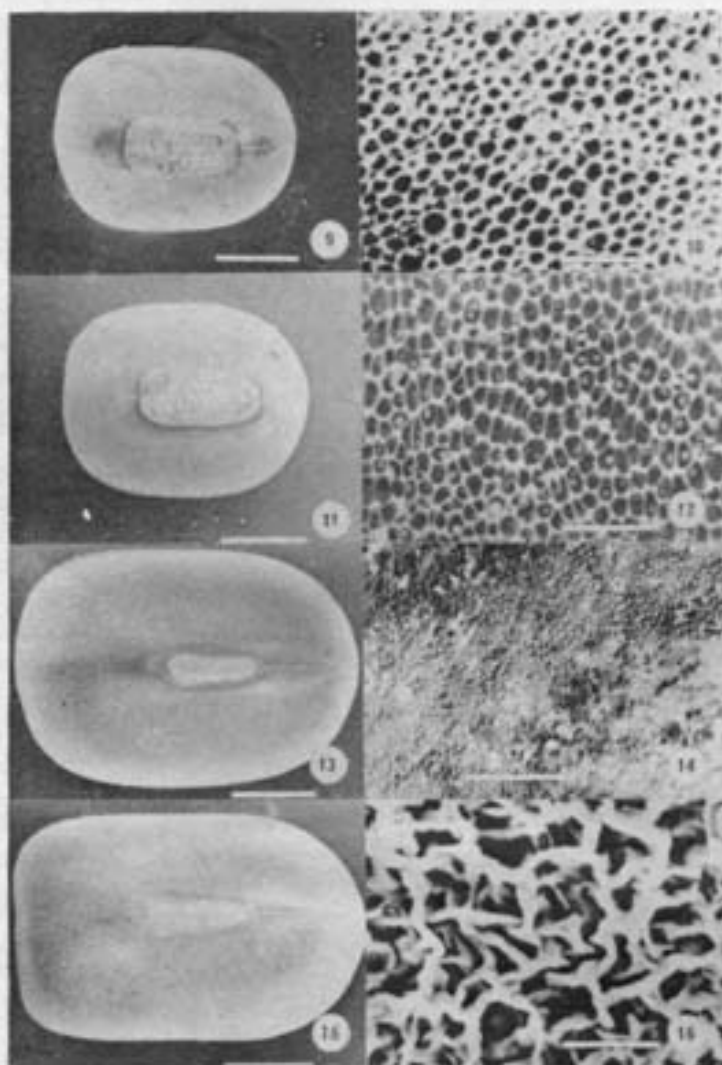


Fig. 9-16. SEM micrographs of seeds of *V. mungo* var. *silvestris*, *V. trilobata* and *V. aconitifolia*. Fig. 9. *V. mungo* var. *silvestris* (PLX 409), globular seed with semi-raised hilum. Fig. 10. Seed coat of PLX 409 with small hexagonal cells arranged in network. Fig. 11. *V. trilobata* globular seed with semi-raised hilum. Fig. 12. Seed coat of *V. trilobata* showing rectangular to hexagonal cells arranged in network. Fig. 13. *V. aconitifolia* cultivated, globular seed with lanceolate hilum. Fig. 14. Smooth seed coat of *V. aconitifolia* cultivated. Fig. 15. Wedge shaped seed of *V. aconitifolia* wild with hilum similar to cultivated. Fig. 16. Seed coat of *V. aconitifolia* wild showing heavy wax deposition. (Fig. 9, 11, 13, 15 -Scale Bar = 1 mm, Fig 10, 12, 14, 16-Scale Bar = 100 μ m).

surface (Fig. 6). Heavy wax deposition on cell walls with unequal quantity was observed. Waxy mounds on cell boundaries exhibited irregular external surfaces. Wax deposition on cell surfaces and sutures was in the form of granules giving papillate appearance to the seed surface. Contours of epidermal cells were quite distinct with irregular thickness.

In the present study, two accessions (PLX 409 and PLX 410) of the wild putative progenitor *V. mungo* var. *silvestris* were studied for their seed coat pattern. The seed coat pattern of wild ancestral form *V. mungo* var. *silvestris* exhibited remarkably similar cell shape, size and configuration with *V. mungo*, but the degree of cell wall distinctness and wax deposition was variable (Fig 8, 10). Interestingly PLX 409 showed remarkably smaller (4-5 times) hexagonal cells typical of *V. mungo-silvestris* complex as compared to the other three wild types.

Vigna trilobata

In this semi-domesticated species, one accession (IC 24830) was studied, seeds were oblong to globular in shape with roundish ends. (Fig. 11). The hilum in this species was lanceolate in shape and not much raised. Seed coat surface structure showed the presence of hexagonal cells arranged in wavy rows (Fig 12). Deposition of wax was rather uniform and thin giving a smooth appearance to the surface. Sometimes unequal wax deposition was found along the cell sutures. Lateral cell walls possessed more wax deposition in comparison to transverse walls. Small papillae were observed on cell surface occasionally. Cell boundaries were distinct, rarely indistinct, forming a regular network of cells on seed surface (Fig. 12).

Vigna aconitifolia

One cultivated (PLMO 211) and one wild type (C2515) accession of *V. aconitifolia* were studied. Seed shape in cultivated forms was globular to elongated with roundish ends (Fig. 13) while in wild forms, it was rectangular to wedge shaped (Fig. 15). The hilum was found to be flattish, elongated, lanceolate and arilate in both the forms (Fig. 13, 15). Cultivated type (PLMO 211) exhibited very smooth, thin and uniform wax deposition on seed surface. Low magnification (250x) revealed the presence of very small, elongated and hexagonal epidermal cells arranged in a reticulate pattern (Fig. 14). In contrast to the cultivated strain, wild type showed thick and heavy deposition of wax on surface forming irregular reticulations (Fig. 16). These reticulations formed by the interweaving of finger like waxy tubercles of varied thickness. Due to such irregular wax deposition, cell boundaries were found to be indistinct with no clear cut suture and cell walls (Fig. 16).

Vigna umbellata

Wild form of *V. umbellata* (IW 3178) was studied in comparison to its cultivar (IC 18136). Seeds in both the forms were globular and elongated with roundish ends (Fig. 17, 19). The hilum in the cultivar was prominent, raised, rectangular in shape and set towards the lower end of the seed (Fig. 17). In the wild accession, the hilum was linear, not much raised and rectangular in shape (Fig. 19). The seed coat in both cultivated and wild forms, was very smooth due to uniform and thin wax deposition (Fig. 18, 20). Waxy pattern on seed coat was not observed in both the forms however, at higher magnification, densely packed epidermal cells with indistinct cell walls were found (Fig. 18, 20). Seed coat surface of wild type showed small irregular patches of wax at some sites.

The taxonomical nomenclature, origin and evolutionary relationships of the cultivated taxa with that of wild-occurring closely related species of the genus *Vigna* have remained complex and blurred.

SEM studies of the seed coat showed that in *V. radiata*, the seed coat possesses elongated cells, mostly rectangular or wedge shaped, arranged in parallel rows with their wall and forming reticulum superimposed with heavy wax deposition on cell boundaries. The wild form *V. radiata* var. *sublobata* possessed similar structure and configuration of cells and remarkable morphological similarities exist with *V. radiata*. *V. mungo* — another important cultivated species and its well authenticated ancestral form *V. mungo* var. *silvestris* exhibited similar seed coat cellular morphology and hilum structure. The two wild forms of *V. mungo* var. *silvestris* (PLX 410 and PLX 409) possessed hexagonal epidermal cells with heavy wax deposition resulting in varying degree of cell wall distinctness. These forms of *V. mungo* var. *silvestris* resembled its cultigen species *V. mungo* with exception of PLX 409 which possessed a hilum like *V. radiata* var. *sublobata* and seed coat structure like *V. mungo* var. *silvestris*.

Sharma *et al.* (1977, 1983) reported the presence of elongated hexagonal cells forming reticulum with varying degree of wax deposition in *V. sublobatus* (*V. radiata* var. *sublobata*). While the present and earlier studies on this complex showed such pattern in *V. mungo* and in its wild form *V. mungo* var. *silvestris* (Chandel *et al.*, 1984; Trivedi and Gupta, 1986). Further Sharma *et al.*, (1977, 1983) wrongly designated wild *Vigna* species collected from Pune, Khandala and Mahabaleshwar regions of Western Ghats as *V. sublobatus* (*V. radiata* var. *sublobata*). This is also contrary to other published reports (Arora *et al.*, 1973; Chandel, 1984; Chandel *et al.*, 1984 and Arora, 1986) that this region has predominant natural distribution of *V. mungo* var. *silvestris* but not of *V. radiata* var.

sublobata. It is relevant to mention here that wild form accession PLX 416, collected from Khandala region of Western Ghats by NBPGR (Arora *et al.*, 1973) was designated as holotype for *V. mungo* var. *silvestris* (Lukoki *et al.*, 1980). The present findings strongly support the view that *V. radiata* and *V. mungo* are two separate species and their wild ancestral forms are *V. radiata* var. *sublobata* and *V. mungo* var. *silvestris*, respectively (Chandel, 1984; Chandel *et al.*, 1984). Conclusions drawn by Jain and Babu (1982) that *V. calcarata* is the putative progenitor of *V. radiata* and *V. sublobata*, *V. mungo*, *V. calcarata* and *V. radiata* are closely related to one another, do not conform with the present studies.

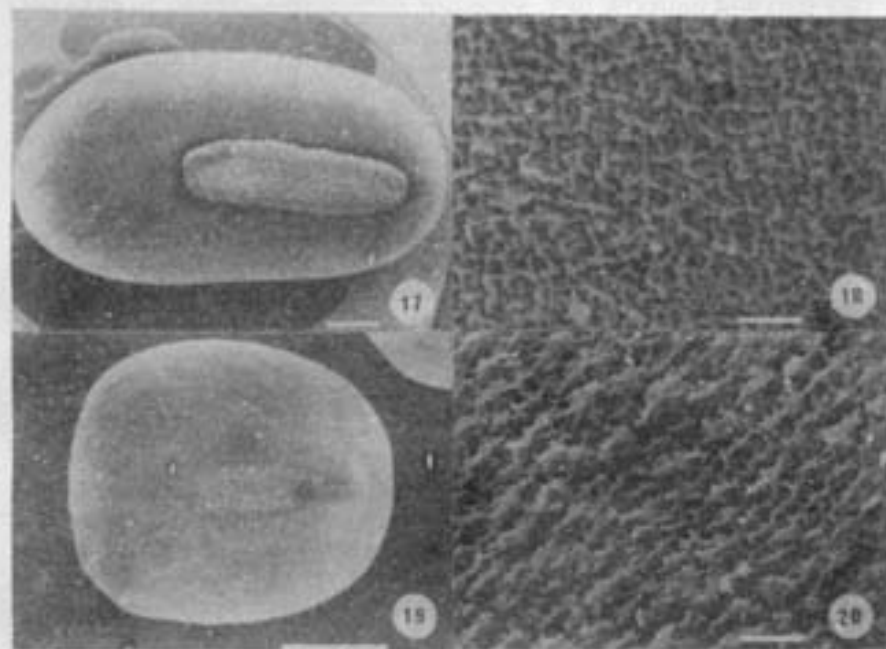


Fig. 17-20. SEM micrographs of seeds of *V. umbellata*. Fig. 17. *V. umbellata* cultivated, globular seed with raised hilum. Fig. 18. Smooth seed coat of *V. umbellata* cultivated, showing epidermal cells. Fig. 19. Globular seed of *V. umbellata* with hilum not much raised. Fig. 20. *V. umbellata* wild, smooth seed coat, epidermal cells with wax deposition at some sites. (Fig. 17, 19-Scale Bar = 1 mm, Fig. 18, 20-Scale Bar = 10 μ m).

Intraspecific variations and overlapping of some seed coat surface characters recorded among the various forms of *V. radiata* var. *sublobata* and *V. mungo* var. *silvestris* may be influenced by interactions between genetic and environmental factors due to their occurrence in different ecological habitats and microniches (Ojomo, 1972; Wyatt, 1984; Matthews and Levins, 1986) or sometimes due to their sympatric distribution (Chandel, 1981, 1984).

SEM seed coat surface structure and hilum morphology of *V. trilobata*, *V. aconitifolia* and *V. umbellata* suggested the distinctness of these species from each other and from *V. mungo* and *V. radiata*. It is important to mention here that seed coat surface pattern of cultivated forms of *V. aconitifolia* drastically differed from its wild type. Thick waxy deposition present in wild form in this species might have become reduced in the course of evolution towards cultivated type where it is very thin and uniform. In *V. umbellata*, definite resemblance in SEM seed coat structure was observed in cultivated and wild types. Thus the present studies clearly indicate species-specific nature of SEM seed coat structure and hilum morphology in these five Asiatic *Vigna* species. SEM seed coat morphology also proved to be useful in establishing phylogenetic relationship between wild and cultivated types in *V. mungo*, *V. radiata* and *V. umbellata*.

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CONSERVATION OF PLANT GENETIC RESOURCES - SOME VIEWS

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Conservation is as vital as collection of genetic resources. How much and how best to conserve remain live problems. Conservation strategies have evaluation as one of the main components. Criteria to identify duplicates in collections still need to converge. There are chances of generation of new variability in 'static' collections of seed in long term storage. Collections are made continuously straining space availability in gene banks. Modern tools like molecular markers may add more to the number to be conserved. This is because collections whose phenotypic performance is very similar could be identified as distinct based on RFLP variation. This could cause a 'load' to the gene bank. A trade-off has then to be worked out among (a) novel genes to be conserved for their own sake (b) accessions with traits of potential use for breeding in the near future and (c) accessions with possible genetic differences as revealed by RFLP markers whose phenotypic expression is near identical in target environment. Further, in order to sustain the dynamic nature of conservation activity, serious thought should be given to conservation of germplasm complexes and populations. In this context, sampling strategies to conserve maximum with minimum number of samples also assume importance. This paper projects considered views and those arising from published work.

Conservation and effective utilization of plant genetic resources (PGR) are essential for global food security as was also stressed in SAREC Report (1992). A detailed action plan to conserve biodiversity and to prevent the extinction of any species including non-threatened stocks has been drawn up by IUCN/UNEP/WWF (1991). Special emphasis was laid on development of techniques to manage small populations of plant and animal species taking into account the need to prevent inbreeding and local extirpation resulting from accidents,

ecological catastrophes and climatic change. Today conservation strategy is based on perceived impending loss of biodiversity that includes interesting species, subspecies or even varieties. The focus is on loss of potentially useful resources such as plants with economic or medicinal value (Erwin, 1991). An area that causes concern and therefore deserves greater attention, is the degradation and conversion of the environments where the target taxa reside. In short, the horizon of the conservation needs is far wider than is being scanned. With scant knowledge on how much total diversity once existed, it is impossible to quantify the losses. But to save what is left of the world's priceless heritage of genetic diversity and to ensure that agriculture meets the needs of the next century and those to follow, we have no alternative but to conserve PGR (Anon., 1991). Yet, more than the need to conserve, how much and how best to conserve are live problems. There is no point in collecting material if it cannot be conserved, nor is there any point in conserving material which cannot be evaluated and utilised (Marshall and Brown, 1975).

COLLECTIONS IN GENE BANKS AND FURTHER NEEDS

It is estimated that size of germplasm holdings of major crop species available in various germplasm banks are: roots and tubers, 75,600; vegetables, 274,600 (Cruciferae 59,600; Cucurbitaceae 131,00); cereals, 11,96,214 (barley 280,300; maize 99,714; rice 212,200; sorghum 91,200; wheat 401,500); Grain legumes 185,140 (*Phaseolus* 70,750); forage grasses 84,200; forage legumes 127,900 (Holden, 1984). These estimates would, nonetheless, be higher now. As a resource-effective policy, IBPGR has been allowing collections only when it is a must. There are other facets of PGR conservation too; for instance (a) *in situ* conservation in natural or original habitat, (b) *ex situ* conservation in gene banks as seed, tissue or pollen, in field gene banks or in other live collections and (c) on-farm/community conservation (Anon., 1991). Viewed against this backdrop, large scale occurrence of duplicates in world gene banks is a severe constraint on purposeful conservation efforts. In some crops, the duplicate collection can probably be as high as 60 per cent (Holden, 1984). In some instances, duplicates of designated collections are encouraged, as a policy, to be maintained in more than one location as an insurance against disaster. But they form only a tiny proportion of the duplicate collections. Alternatively, the problem of identifying true duplicates when a large number of qualitative and quantitative traits characterize a collected genotype, is too complex. At the same time, increasing emphasis is also laid on conserving wild relatives of crops to sustain breeding efforts on incorporation of resistance to biotic and abiotic stresses. For example, the international rice germplasm centre holds over 2,300 populations of 25 wild species

including 5 species in 3 genera related to *Oryza* (Zuno *et al.*, 1988). Such activities stress, in turn, conservation of habitats of such wild species. Conservation of wild species, in its broad sense, has thus become an important activity of gene banks (Plucknett *et al.*, 1987). But outdated taxonomic classification, for example, of sorghum (Snowden, 1936) and poor adaptation of wild species to target environments as observed in *Oryza barthii* and *O. longistaminata* in Philippines and *Sorghum drumondii* in Illinois pose hurdles in their effective utilization (Harlan, 1984).

There is then a need for formulation of sampling procedures for species where exploration is a limiting factor, such as species threatened by extinction and those that occur in difficult and remote terrains. Some of them can be explored only once and the responsibility of the explorer is then immense. Further, conservation of too many accessions in one crop or species is necessary for maintaining the real variability, will curtail the resources and infrastructure for conserving another, probably more important, crop or species (Marshall and Brown, 1975). It has been conjectured that a barley collection of just 12,000 probably may contain a majority of barley genes (Creech and Reitz, 1971).

Conservation programmes need to be coordinated and systematically planned according to the crop specific limits and factors limiting the number of germplasm collections that can be made. Monitoring of resources for conservation will be facilitated if an estimate of the genetic variability trapped in the collections can be obtained with a reasonable reliability. It would simultaneously be of interest to take note of the conservation methods so as to minimise the decay of genetic variability. In particular, the progressive decay of variability over generations needs to be considered in relation to the strategy used such as selfing, planned crossing and the pollinating system of the crop.

GERMPLASM MAINTENANCE

Most of the PGR are maintained by growing them periodically in the field. In general, partial and complete outbreeders may exist in a germplasm bank. Depending on the seed requirement, a small sample (varying in size, may be 10 to 50 plants) is grown in the field. In the process, unless pollination is entirely controlled, new genetic variability can be generated. Further, where open pollinators are liable to show inbreeding depression (affecting survival), full sib mating is resorted to which will also result in slow erosion of heterozygosity. It is further recognised that distinctly different accessions grown in field, are subject to optimising natural selection against extreme variation that usually occurs despite developmental buffering (Travis, 1989). The argument that phenotypic plasticity would buffer the effects of natural selection

is not valid as it is now clearly known that genotypic performance in one environment can differ markedly from another. Such a response to varying environments can be considered to be adaptive only if it represents a mechanism for maintenance of relative fitness in the face of such variation. Then, in principle, evolutionary changes can result despite phenotypic plasticity (Thompson, 1991). Further, in the presence of some degree of pollen dispersal, particularly in populations with a low selfing rate, it has been shown by computer simulation that there is a chance for 'periphery effect' — the uneven distribution of genotypes at the periphery of a population compared to its central region (Yonezawa, 1989). This result adds to the problem of maintenance of populations. When extended, such concepts will hold to situations where (and, as usually, is) a number of distinctly different accessions are usually grown together in adjacent strips in field for maintenance. In particular, active gene flow between accessions can lead to differential loss of genetic distinctness.

GERMPLASM EVALUATION

Evaluation is a very important component of a gene bank's function and has a close relevance to conservation activity. The breeding worth of an accession can be realised only if it is evaluated including quantitative traits-morphological, physiological, biochemical and the like. They would serve as additional and essential data to passport information. Breeders from near gene bank location can straightway use the data for selection saving an evaluation at their experimental sites and those in areas far away from the gene banks can select accessions at the first stage to be evaluated in their environment for confirmation and second stage selection.

Multivariate analysis (for example, using D^2 statistic, principal components, factor analysis etc.), numerical methods (like dendrograms), modification of multiple range test of univariate means providing 'performance indices' (Arunachalam, 1992) and variations of the above methods are generally used for quantitative evaluation of germplasm accessions. The methods are well known and documented. By these methods, the genetic diversity among accessions is examined and closely related stocks are grouped into a cluster. If the constitution of clusters and the relative genetic distances of various clusters (formed out of a set of accessions) remain stable over environments (time and space), there is a scientific validity to maintain the accessions within a cluster as a germplasm complex. There would be divergent opinions regarding on how large an accession, in how many environments and over how many quantitative traits, the evaluation should be done. These questions would not admit of unique solutions. It may be observed however, that

such exercises are essential for every gene bank to restrict growth of duplicates and more importantly to make space to receive more, possibly very important, accessions.

MOLECULAR TECHNIQUES IN GERMPLASM EVALUATION AND CONSERVATION

The advent of *in-vitro* techniques particularly tissue culture has helped in widening the base of conservation and enhanced the scope for effective utilization of PGR. Conservation of germplasm as tissue cultures and their regeneration and evaluation have been well documented and will not be dealt with here.

Of recently growing interest, adding a new dimension to the scope of plant breeding, is the use of molecular markers in genetic identification. Such markers identified through restriction fragment length polymorphism (RFLP) have been suggested to have the potential of bringing more definiteness to conventional breeding. RFLP markers have been credited with unique advantages compared to conventional (morphological) phenotypic markers. RFLP-based linkage maps are projected to help identify molecular markers that would have close linkages with useful quantitative trait loci (QTL) of economic interest. The processes, concepts and methods have been frequently documented (Beckman and Sollar, 1986; Tanksley *et al.*, 1989). A series of papers on improving soluble solid content in tomato, the use of RFLP markers as a novel and viable technique of plant breeding and enormity of such molecular investigations on tomato has been described, (Paterson *et al.* 1991). RFLP markers have been used in germplasm characterisation by several workers. Five DNA probes used to evaluate 77 individuals from 5 lucerne germplasm groups revealed high polymorphism with 7-9 bands each. Cluster analysis suggested only three clusters among the 5 groups. Correspondence between conventional and molecular evaluation of diversity was made difficult by the small number of individuals and probes (Walton *et al.*, 1988). RFLP patterns suggested identity between modern cultivars and three wild accessions in soybean. The suggestion was that the wild accessions collected from China were of hybrid origin with *Glycine max* as the maternal parent in natural out-crossing (Close *et al.*, 1988). Extensive RFLP variation was found at the species, subspecies and varietal levels in *Brassica* (Song *et al.*, 1988). RFLP markers were also useful in genetic differentiation in cultivated rice (Takaiwa and Oono, 1991). Nevertheless how far RFLP markers can successfully substitute phenotypic markers, that indicate genotypic expression in target environment, is an open and debatable area. Papers projecting the other side of the RFLP advantages have also been appearing (Ellis, 1986; Blake *et al.*, 1991; Simmonds, 1991). The pros

and cons of employing RFLP markers in germplasm evaluation and conservation will only be discussed here. RFLP markers are DNA sequences detected by restriction enzymes. RFLPs are detected as bands in agarose gels and, therefore, do not have 'phenotypes' in the conventional sense. In general, they do not code for a gene function and cannot therefore have independent phenotypic expression. Most often their linkage to a continuously varying quantitative trait of interest is judged by LOD (a maximum likelihood) score. Such markers can be several, in principle, as a very large number of probe-enzyme combinations are available. Even though 'linkage' can be inferred between a marker and a quantitative trait in one stock, it cannot immediately imply that, whenever the presence of the marker is detected in any other stock, it would have the desired value of the quantitative trait. The reason may be that every quantitative trait is governed by a number of minor genes with small effects which are further modified by environment during expression. Further, most of the traits of breeding (and also gene bank) interest are quantitative in nature. A few RFLP markers, which are codominant and nonepistatic, cannot predict the quantitative trait expression of an accession.

Moreover gene banks can suffer a possible 'load' by molecular marker-based germplasm diversity. Consider, for instance, two accessions, A and B which were evaluated for a number of quantitative traits and did not show significant differences in a target environment. They will be classified genuine duplicates and will be held in the germplasm bank as a single mixture, in general. If A and B were compared using say 20 probes, it is highly likely that they would be polymorphic for one or a few of them suggesting they are distinct accessions leading to individual maintenance. Extending this logic, it is possible that genuine duplicates would get individual identity by molecular markers causing the 'load' mentioned earlier. The argument that differences suggested by the RFLP markers can be genuine does not hold strength as phenotypic expression (which was earlier argued to be independent of the presence of markers) would be too uniform to uphold it. Further, the performance of an accession for more than one trait would be difficult to be judged by RFLP markers as then, we would be dealing with a multitude of them (taking into account that more than one marker may be linked to one quantitative trait). Moreover, the cost of using molecular markers for germplasm identification is far more at present compared to the cost of field-screening of germplasm accessions (Blake *et al.*, 1991). Thus with the present knowledge, there appears to be no safe premise to advocate the use of RFLP markers over conventional quantitative methods in germplasm evaluation.

SOME STRATEGIES FOR OPTIMISING CONSERVATION

Optimum conservation is a function of abundance of a target species, *a priori* knowledge of the frequency of alleles to be conserved, the number of sites where the target species occur, the distribution of rare alleles and the resource (time, cost, manpower) availability. Other than the last variable, it is most often difficult to get adequate information on others. Even when the status of all the variables is known beforehand, it is difficult to frame optimum strategies of sampling the target site. An ideal strategy is the one which helps to conserve maximum diversity with minimum number of samples. In addition, it is desirable to conserve at least one sample of each of the different alleles in the target species (Bennett, 1970; Marshall and Brown, 1975). This would demand information, for example, on whether the allele is highly or moderately frequent or rare. Some estimates place about two alleles per polymorphic locus occurring in intermediate frequencies in natural populations (Clegg and Allard, 1972) in *Avena barbata*, for example. However, such estimates are experiment-specific and cannot be generalised. Likewise, estimates on sample sizes necessary to represent a target species were attempted (Marshall and Brown, 1975). When no information was available on variation in a target species, a random sample of size 100 and when such information was available, a sample of size 50 plants per population were suggested. Those estimates contrasted the size of 200-300 plants suggested earlier (Bennett, 1970; Allard, 1970). Since none of those estimates were general enough (and dependent on the conditions of simulation of theoretical basis), it would seem that a safe strategy is to sample as many sites as possible using a realistic sample size constrained only by the available time and resources.

Conservation requires regeneration of PGR at periodic intervals to maintain seeds. With modern methods of seed storage including long term cryopreservation, the intervals for regeneration can be extended from a few to 20-25 years or more. In this process, loss and alteration of genetic variation through differential survival and selection during 'static' storage are factors to be reckoned with. Once the seed stocks are grown in field, the need to identify optimal mating systems and the size of progeny to be used for collecting seeds assumes critical importance. A pairwise mating system that provides $N/2$ matings out of N plants has been suggested. One progeny each from direct and reciprocal mating is saved to get seeds from a total of N progeny plants (Gale and Lawrence, 1984). This need not necessarily be the ideal system. For example, a trait recovery programme has been written for personal computers (Mansur *et al.*, 1990) which calculates the number of progeny that must be raised with a confidence level P to recover a specific

number of progeny (r) possessing a trait or genotype which occurs with known probability q . Calculations can be made for chosen values of p , r and q and the programme does fast and reliable estimation. A number of alternatives using the genetic principles of mating designs can also be thought of. The pollinating system, the extent of genetic variation within and between accessions, the traits for which variability needs to be preserved and the number of accessions to be regenerated in every cycle are a few important parameters to reckon with in deciding the strategy. In such decisions, the principle rarer the allele to be conserved higher the progeny size - is also to be kept in mind (Gale and Lawrence, 1984).

CONSERVATION OF GENE COMPLEXES

Finally, every gene bank has to seriously consider the possibilities of conserving populations and germplasm complexes. A realistic conservation activity would also take into account the 'utility index' of germplasm accessions in enhancing crop productivity (Arunachalam, 1988). Such yardsticks are necessary to keep the conservation process dynamic. In this context, the importance of 'species richness' consisting of the number of species and the richness of 'activity', each species undergoes in its target habitat when transferred from its original one, has been emphasized (Erwin, 1991). Intraspecific variation has been found to influence population gene diversity and hence the effective population size both in outbreeding and inbreeding species. This inference has been arrived at examining allelic frequency at isozyme loci in inbreeding and outbreeding plant species (Schoen and Brown, 1991). Crop variety mixtures have been found to fare well compared to their individual components particularly in marginal conditions varying in time and space (Jiggins, 1990). The possibility of enriching diversity by farmers growing such mixtures over time has been pointed out. In unmanaged pastures, deliberate incorporation of variability has been observed to be beneficial. Reinforcing physiological effects resulting in efficient utilization of growth factors have been postulated in favour of cultivar mixtures (Stutzel and Aufhammer, 1990). High build-up of parastic complexes would be dampened by systematic use of mixtures.

Viewed in the above background, and taking, other constraints on germplasm banks into account, there seems to be scientific logic for conserving germplasm complexes when the need arises. The opinion against conservation of 'mass reservoirs' in preference to maintaining individual components though lacking in diversity, would need critical review. Nevertheless, caution is needed to be conscious that genetic identity of individual components of a population or germplasm com-

plex would be lost over time or new genetic variability could be generated in open and often cross pollinated species. The horizon of germplasm conservation which includes the major component of evaluation is thus much wider and fast expanding with increasing information input. This could be a reason why the question, 'What genetic and germplasm stocks are worth conserving?' (Goodman, 1990) is being repeatedly asked. Though there is no unique answer, possible solutions from intensive research in light of summation given above can only be expected to feasibly converge.

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GENOTYPES OF *POPULUS* AND THEIR EVALUATION IN TERAI REGION OF UTTAR PRADESH

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Owing to their specific photoperiodic requirements, different exotic genotypes of Populus were introduced in Terai region of Uttar Pradesh. The indigenous clones were also developed from open pollinated seeds. Their screening was conducted in nursery to select promising ones which were further studied in populeturns. Afterwards they were evaluated in field. Overall performance of indigenous and American clones was found better than those obtained from other sources. Some of the outstanding clones were S7C15, S7C20, G-48, I-18/62, L-34, L-52, EL-74, S7C1, D-75, L-51/84, L-154/84, L-301/84 etc.

Poplar is a fast growing, multipurpose wood species, distributed throughout the forests of temperate and cold regions of Northern Hemisphere between 30°N and 45°N. There are exceptions found further down to equator even other side of it (Chaturvedi, 1981). Indigenous Poplars have a limited distribution (Mathur and Sharma, 1983). However, none of the Himalayan species are important for timber production (Chandra, 1986). This led to introduction of exotic Poplars in Sub-montane and Terai region of Uttar Pradesh. From initial experiments with different species of *Populus*, it was concluded that suitable clones of *Populus deltoides* (timber producing species) and its hybrid (*P. x euramaricana*) can be successfully cultivated in Terai belt of 28°-30° parallel (Seth, 1969). Since then hundreds of clones (genotypes) of *P. deltoides*, *P. x euramaricana*, *P. nigra* and *P. trichocarpa* have been introduced for nursery and field trials under Terai conditions. Simultaneously indigenous clones were also developed from introduced as well as locally collected open pollinated seeds, and evaluated. Some details of collections, maintenance, nursery and field testing of different clones of *Populus* species are discussed in this paper.

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MATERIALS AND METHODS

Exotic clones introduced from Afghanistan, Australia, Austria, Germany, Italy, Netherlands, Pakistan, Turkey, USA and locally developed ones at Lalkua in Nainital district were first tested in nursery. Nursery testing, populetum establishment and field evaluation were done at Lalkua, Gangapur Patia and Phoolbagh under Silviculture Division, Sal Region, U.P. during last decade. Check clone used was an Australian G-3 of *Populus deltoides*. Location, soil characters and meteorological data of the three experimental sites are as follows:

LOCATION DATA

Characters	Lalkua	Gangapur Patia	Phoolbagh
Latitude	29°10'N	29°7'N	29°7'N
Longitude	79°40'E	79°40'E	79°27'E
Altitude	256m	247m	248m
Soil type	Sandy loam to loam	Sandy loam to loam	Sandy loam to clayey
Soil pH	7.15	7.0	8.1
% Organic Carbon	70	79	71
Exchangable K_2O (Kg ha ⁻¹)	207	184	168
Exchangable P_2O_5 (Kg ha ⁻¹)	165	160	120
Soil depth	1-2m	2-3m	2-3m

METEOROLOGICAL DATA

Month	Temperature°C		Rainfall (mm)
	Mean Max.	Mean Min.	
January	20.7	7.0	44.7
February	22.9	9.2	36.0
March	29.7	13.9	14.9
April	35.7	19.6	28.9
May	38.5	24.2	6.3
June	37.0	26.0	126.7
July	32.5	25.2	471.1
August	31.5	24.8	398.5
September	31.9	23.4	320.2
October	31.2	17.7	15.7
November	26.7	11.1	2.5
December	21.7	7.3	14.4

The cuttings were planted vertically in well worked nursery beds of 10m x 4m size in a randomised block design (RBD) with 3 replications. 7 x 7 cuttings per replication were spaced at 80 cm x 60 cm. About 200 kg farmyard manure was applied per bed. Irrigation was done twice a week till onset of rainy season. Weeding and hoeing were done frequently as and when required. In case of two or more sprouts, singling was done. One year old plants were measured individually. Promising clones were preserved in populeturns.

Populeturns were created by planting entire transplants (ETP) in RBD. ETP pre-treated with Emison, a fungicide, and Aldrin, an insecticide, were planted in 75 cm x 30 cm x 30 cm pits. Number of plants per replication was generally low and spacing was kept at 5 m x 3 m. Irrigation was done weekly in first year and fortnightly in second year till the onset of rains. Hoeing and weeding were done as and when required. Data were recorded annually on different characters like branching habit, leaf fall, leaf sprouting, disease susceptibility etc. on individual plants.

For field evaluation, the clones performing well at nursery and in populeturn were selected and evaluated. Planting method adopted was the same as in case of populeturns. Plants per replication were high, generally 49. Measurements were recorded annually to assess the high yielding promising genotypes. Good survival per cent, height, diameter, disease resistance and straight bole upto a considerable height were the parameters chosen for selection of promising clones both in nursery and field testing.

RESULTS AND DISCUSSION

Nursery testing

Indigenous clones (126) were tested in 1982 for five consecutive years and 9 promising clones (L-12, L-13, L-29, L-30, L-34, L-49, L-52, EL-74, and EL-89) were further screened for field trials. Clones L-12 and L-13 exhibited top branching, leaf crumpling and reduction in leaf size and plant height due to incidence of *Scriptothrips dorsalis*. Same symptoms were observed on mother clone G-48 also. However, plants recovered very fast immediately after few initial showers. In another experiment in 1986, a set of 168 exotic clones introduced from U.S.A. were tested in nursery for four consecutive years. Some of the *P. deltoides* clones (3-8, 9-8 and 64-047-5) did not sprout, others showed inferior growth than control. All the *P. trichocarpa* clones were seen infected. Only 10 promising clones of *P. deltoides* (S7C1, S7C2, ST-72, 64-243-1, 110120, 110702, 113324, S7C4, 1467 and 111828) were finally selected. In third experiment, eighty nine clones (exotic and indigenous) were screened in 1986. L-29, L-30, L-34, L-49, EL-125, L-39, L-52, EL-183,

EL-83 amongst indigenous clones and A-24, ST-6, S-748/111, 4/68, 61/58, 69/55, S7C15, 63/51, 3-12(5), 73/53(7), Fereillo, 2504 amongst the exotic clones were scored as promising. Another set of indigenous clones of 1984 selection were screened in nursery for three years. More than forty clones were found promising. As indicated by initial performance, selections done during 1984 were better than the 1982 selections. In 1989, nursery testing of 610 indigenous hybrid (*P. ciliata* × *P. deltoides*) clones was started. After two screenings, 22 clones have been found promising. Among them, best ones are L-24/88, L-40/88, L-52/88 and L-66/88. The offsprings in these cases, have inherited dominant characters from female parents e.g., leaf shape and size, good growth, stem form etc.

Populeturns

About 300 clones (exotic and indigenous) were preserved in the populeturns established in different years at two sites i.e., Gangapur Patia and Phoolbagh. Some of the significant characters studied are compiled in Table 1 and 2. Leaf size is the average length and width of fifty leaves selected randomly. Whole range (leaf length) is categorized into three groups, i.e., large (13.1cm-17cm), medium (9.1cm-13cm) and small (5cm-9cm). Leaf size of control clone falls under medium category. Leaf fall and leaf sprouting period indicates completion of leaf shedding and starting of leaf sprouting. Completion of the latter was observed within 20-30 days.

Field performance

Sixty exotic clones were put under evaluation trial in 1985. After six years of growth, nine clones, i.e., D-75, S7C20, S7C8, D-66, S7C15, S7C1, 2502, 72/58 and 69/55 proved promising. In 1986, thirty four clones (both exotic and indigenous) were planted for field evaluation. Sixteen clones G-48, I-18/62, S7C15, S7C8, D-82, S7C20, D-124, L-12, L-49, EL-74, L-34, EL-71, L-30, L-29, L-52 and EL-89 were found better than check clone (Australian G-3). Indigenous clones transplanted in the field in 1986 produced some superior clones which are L-12, L-13, L-22, L-29, L-30, L-34, L-49, L-52, EL-67, EL-74, EL-89, EL-114, EL-117 and EL-125. In general, clones of local origin (L) were better than those of exotic ones (EL). Out of seventy five exotic clones tested in field in 1988, fourteen clones i.e., S7C1, S7C2, 82-33-3, 110120, 110702, 113324, S7C4, 1467, G-48, D-121, 3324, 82-40-2, S4C2 and 3565 were promising. All these selected clones except G-48 are of American origin. A set of indigenous clones of 84 selection were also put in field. They showed much better growth than any other clones. On the basis of comparative growth performance and other characters like good stem form and disease resistance, different clones were categorised into three groups viz., good, promising and poor (Table 1 and 2). The control clone G-3 is of

Table 1: Characteristics of promising genotypes of *Populus deltoides*

Clones	Source Origin.	Average leaf size	Leaf fall week	Leaf sprouting week	Sex and other characters
G-3 (Control)	Australia	medium	Jan. I	March-IV	Male, Pygaera attack .
G-48	Australia	medium	Jan. I	March-IV	Female
65/27	Australia	small	-	-	Evergreen
D-121	U.S.A.	medium	Dec. III	March-IV	Female
L-12	India*	medium	Dec. IV	March-IV	-
L-29	India*	medium	Dec. IV	March-II	-
L-30	India*	small	Jan. I	March-II	-
L-34	India*	medium	Jan. I	March-III	-
L-23/84	India*	medium	Jan. I	March-II	Forking
L-24/84	India*	medium	Dec. III	March-III	-
L-39/84	India*	medium	Dec. IV	March-III	-
L-51/84	India*	small	Dec. IV	March-II	-
L-55/84	India*	medium	Jan. I	March-III	-
L-71/84	India*	small	Dec. III	March-II	-
L-72/84	India*	medium	Dec. III	March-II	-
L-133/84	India*	medium	Dec. II	March-II	-
L-142/84	India*	medium	Dec. III	March-III	-
L-153/84	India*	medium	Jan. I	March-II	-
L-154/84	India*	medium	Dec. III	March-II	-
L-162/84	India*	medium	Jan. I	March-III	-
L-169/84	India*	small	Dec. IV	March-II	-
L-215/84	India*	medium	Dec. II	March-III	-
L-247/84	India*	small	Dec. IV	March-II	-
L-301/84	India*	medium	Dec. III	March-II	-
L-303/84	India*	small	Dec. IV	March-III	Pygaera attack

* Nainital, U.P.

TABLE 2: Promising genotypes of *Populus deltoides*

Sl. No.	Clones	Source/ Origin	Sl. No.	Clones	Source/ Origin
1.	74/24	Australia	46.	69/55	Italy
2.	S-748/111	Australia	47.	Eco-28	Italy
3.	28/13	Australia	48.	Spido	Italy
4.	69/58	Australia	49.	2502	Netherland
5.	P.'IC'	U.S.A.	50.	2503	Netherland
6.	D-61	U.S.A.	51.	2653	Netherland
7.	D-66	U.S.A.	52.	2656	Netherland
8.	D-67	U.S.A.	53.	2673	Netherland
9.	D-75	U.S.A.	54.	3650	Netherland
10.	D-82	U.S.A.	55.	3686	Netherland
11.	D-124	U.S.A.	56.	L-13	India*
12.	D-171	U.S.A.			India*
13.	S7C1	U.S.A.	57.	L-49	India*
14.	S7C4	U.S.A.	58.	L-52	India*
15.	S7C8	U.S.A.	59.	EL-74	India*
16.	S7C15	U.S.A.	60.	EL-117	India*
17.	S7C20	U.S.A.	61.	EL-125	India*
18.	S4C2	U.S.A.	62.	L-57/84	India*
19.	ST-66	U.S.A.	63.	L-58/84	India*
20.	ST-67	U.S.A.	64.	L-62/84	India*
21.	ST-92	U.S.A.	65.	L-68/84	India*
22.	ST-109	U.S.A.	66.	L-49/84	India*
23.	118	U.S.A.	67.	L-75/84	India*
24.	3167	U.S.A.	68.	L-129/84	India*
25.	3263	U.S.A.	69.	L-130/84	India*
26.	3324	U.S.A.	70.	L-152/84	India*
27.	3567	U.S.A.	71.	L-158/84	India*
28.	721502	U.S.A.	72.	L-165/84	India*
29.	82-33-3	U.S.A.	73.	L-168/84	India*
30.	82-42-5	U.S.A.	74.	L-176/84	India*
31.	82-40-2	U.S.A.	75.	L-179/84	India*
32.	63/51	U.S.A.	76.	L-181/84	India*
33.	I-18/62*	Pakistan	77.	L-182/84	India*
34.	A-13	West Germany	78.	L-188/84	India*
35.	A-26	West Germany	79.	L-198/84	India*
36.	A-37	West Germany	80.	L-200/84	India*
37.	A-194	West Germany	81.	L-224/84	India*
38.	1/56	West Germany	82.	L-229/84	India*
39.	2/56	West Germany	83.	L-290/84	India*
40.	TRIPLO*	Italy	84.	L-291/84	India*
41.	Luisa-Avanzo*	Italy	85.	L-293/84	India*
42.	CIMA*	Italy	86.	L-296/84	India*
43.	GUARDI*	Italy	87.	L-297/84	India*
44.	Lux	Italy	88.	L-299/84	India*
45.	ONDA	Italy	89.	L304/84	India*

* clones of *P. euramaricana*

* Nainital, U.P.

Australian origin which was an American selection and an established commercial clone of *Terai* region. Out of 291 clones evaluated, 24 were good, 89 promising and 178 poor. Among 24 good clones, 2 were of Australian, 1 of United States and remaining indigenous origin. Majority of the promising clones were either indigenous (57%) or American (31%). German, Dutch and Italian clones showed poor adaptability to *Terai* conditions. This may be due to latitudinal correlation of the place (Tiwari 1988).

The observation revealed that planting height and diameter of ETP do not affect overall growth of the tree significantly. This supports earlier reports of Chaturvedi (1981) and Singh (1989). However, growth of few promising clones, i.e., S7C1, S7C4, S7C15, G-3, L-12, L-13, L-34, G-48 were found enhanced when grown in combination with medicinal plants and agricultural crops as intercropping practice. Earlier findings of Mathur and Sharma (1983), Anonymous (1987), Singh *et al.* (1988) and Jha and Gupta (1991) were also in agreement with this.

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SOYBEAN GENETIC RESOURCES AND THEIR EVALUATION

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Soybean (Glycine max) is one of the important crop in the United States and the world's richest source of protein and leading source of vegetable oil. It has the unique protein and oil combination (40% protein and 20% oil). Although soybean is a new crop in our country, it has occupied a substantial acreage in the last 22 years from 3000 hectares in 1968 to presently nearly 20 lakh hectares. The National Bureau of Plant Genetic Resources is engaged in collection/exchange, characterisation/evaluation, documentation and conservation of genetic diversity of soybean for the last two decades. A total of 2,639 accessions of soybean from diverse agro-climatic zones of the world (from 30 countries including India), were evaluated for two years i.e., 1988 and 1989. Data were recorded on 21 agro-botanical and economic characters and donors were identified for different economic traits, viz., high yield, early maturity, bold seeds, resistance to bacterial pustule and pod blight, high seed longevity/germinability, resistance/tolerance to pod shattering and high oil content. These donors can be utilized either as parental material in hybridization or as direct selections for crop improvement programme.

Soybean (*Glycine max* (L.) Merrill) now occupies third place in vegetable oil production in India. It holds good promise owing to its 40 per cent protein and 20 per cent oil. In India, average yield of soybean (900 Kg/ha) is rather low compared to the world average of 1800 Kg/ha and Asian average of 1200 Kg/ha. Thus, it is quite imperative to exploit available genetic variability to enhance the yield and other economically important traits. Considerable variability has now been assembled through introduction and collection from several countries by the NBPGR. The present paper highlights the efforts on evaluation/characterisation of world genetic resources in soybean.

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MATERIALS AND METHODS

The NBPGR and the erstwhile Plant Introduction Division of the Indian Agricultural Research Institute, New Delhi assembled 2,639 germplasm accessions from 30 countries (Table 1). In India, various areas were explored and variability was collected from several pockets in Kumaon region of Uttar Pradesh, Bihar, Madhya Pradesh, Himachal Pradesh, Maharashtra, Sikkim, Manipur, West Bengal, Meghalaya and Arunachal Pradesh.

Table 1. Augmentation of soybean germplasm in India

Source (Number of accessions)	Total Accessions
1. Exotic germplasm	1,645
USA (493), Canada (12), South Africa (2), Australia (111), Germany (188), China (19), Nepal (44), USSR (63), Italy (36), UK (11), Argentina (196), Hungary (64), Taiwan (189), Morocco (4), Nigeria (53), Thailand (6), Romania (15), Sri Lanka (2), Trinidad (1), Philippines (13), Brazil (31), Yugoslavia (1), Papua New Guinea (3), Ghana (13), Israel (1), Korea (2), Rhodesia (3), Indonesia (4), Fiji (9) and Japan (56)	
2. Indigenous germplasm	994
Uttar Pradesh (199), Punjab (18), Himachal Pradesh (167), Sikkim (15), West Bengal (14), Assam (2), Meghalaya (26), Madhya Pradesh (156), Manipur (21), Bihar (39), Maharashtra (205), Gujarat (18), Jammu & Kashmir (41), Mizoram (25), Arunachal Pradesh (8), Rajasthan (7), Delhi (25), Karnataka (7) and Tamilnadu (1).	
Total	2,639

The entire soybean germplasm is being maintained at NBPGR, Regional station, Akola (Maharashtra). The accessions were grown in augmented block design at NBPGR Experimental Farm, Akola and evaluated during *kharif* seasons of 1988 and 1989. Row length was 3 m per accession and row to row distance was 60 cm. MACS-13 and Bragg were used as controls and grown after every 25 accessions. Observations were recorded on growth habit, days to flowering and maturity, flower colour, pubescence colour, pubescence type, pubescence density, number of leaflets and their shape, leaf colour, plant height, pod colour, seed coat colour, hilum colour, number of seeds per pod, grain yield per plant, 100-seed weight, oil content, pod shattering, lodging, reaction to bacterial pustule, soybean mosaic and pod blight.

Two hundred accessions were screened through methanol stress test (20% solution V/V, 2 hr., followed by normal laboratory germination test). Per cent germination was determined, using 1 cm of emerged radicle as the criterion for germination. Accessions showing more than 80 per cent germination under methanol stress test were considered as high seed germinability accessions. Pod shattering was recorded after 7-10 days of physiological maturity.

RESULTS AND DISCUSSION

The soybean variability provides vast potentialities for exploiting various useful economic traits. The accessions varied for days to flowering (25-72 days), days to maturity (68-148 days), plant height (10-210 cm), number of leaflets (3-5), number of seeds per pod (1.6-3.1), yield per plant (1-27.0 g), 100-seeds weight (0.3-44.4 g) and oil content (8.6-24.0 %). The early introductions that had been initially found suitable for cultivation were Bragg, Clark-63, Lee, Davis, Hardee and Monetta. With increase in area under these varieties, it was soon realised that these varieties were highly susceptible to diseases and insect pests. They also suffered from poor germinability and were mostly photosensitive. Early maturing varieties of soybean have been found to be less sensitive to photoperiods than late maturing varieties (Johnson *et al.*, 1960). Therefore, the lines having early maturity (68-75 days) were considered as insensitive to photoperiod (Table 2). These lines may possibly be used as donors for introducing photoperiod insensitivity. However, these genotypes were inferior from yield point of view.

Widely adapted varieties Bragg, Clark-63, Hardee etc. were susceptible to yellow mosaic virus. PI-171443 (UPSM-534) and wild soybean (*Glycine formosana* Hosokawa syn. *Glycine soja* Sieb. & Zucc.) were reported to be resistant sources to yellow mosaic virus (Singh *et al.*, 1974a; 1974b). Several yellow mosaic virus free genotypes were earmarked, viz., PK 416, PK 472, PK 515, PK 719, PK 727, PK 733, PK 746 and PK 749. However, the incidence of yellow mosaic virus was not severe in both the years. Several genotypes, viz., EC 34094, EC 95806, EC 106991, EC 106992 and EC 106998 were identified having field resistance to bacterial pustule (Table 2). Groth and Braun (1986) reported that 'rxp' as single recessive gene confers resistance to bacterial pustule in soybean. Therefore, resistance can be transferred from donor source to high yielding cultiars by using either pedigree method or simple back cross method of breeding.

Storage of soybean seeds under ambient conditions usually causes rapid deterioration. Loss of seed vigour and viability is accelerated by high ambient temperature and high relative humidity. By using methanol stress test, several genotypes were identified for high seed ger-

Table 2. Donors identified for various traits

Traits	Donor accessions
Early maturity	EC: 34160, 34362, 26998, 37072, 37083, 28138, 38140, 39018, 39020, 29039, 39040, 39041, 39042, 39146, 39152, 39154, 39157, 39198, 39230, 39242, 62818, 65772, 93372, 93384, 232019, 232075, 232080, 232082 A, 250575, 250578, 250607, 250608, 250609, 251771, 251774, 251775, 251776 and Monetta IC: 16569, 18382, 18748, 18758, 18759, 18761, 18486, 24529, 96391, 96396, 96449
High grain yield (18–27 g/plant)	EC: 9316, 11741 A, 14434, 26692, 34041, 34146, 34279, 371093, 9014, 39025, 39036, 39081, 39222, 93493, 95673, 118309, 172660, 241780, 241843, 241929, 242033 A, 245482m 245981 A, 245985 A, 245988, 251372, 251410, 251410, 251411, 251434-A, 251477, 251484, 251517, 251713, 251829, and 251869 IC: 574, 18381, 18383, 24072, and 41680
100-seed weight (15–44.4 g)	EC: 39755, 55888, 93365, 127508, 241110, 241780, 241977, 242022, 245981-A, 245985-A, 245988, 251515, 251517, 251529, 257977, 257978, 301883, and 301884. IC: 16570, 18381, 96411, 96416, and 96419
Field resistance to bacterial pustules.	EC: 34094, 95806, 106991, 106992, 106998, 36963, 36088, 39094, 95272, 95291, 10002, 100031, 100801 IC: 202, 210, 2043, 13005, 24072, 24373, 6345 and 96357
Tolerance to pod blight	EC: 106991 and 106992
High seed longevity/ germinability.	EC: 99991, 101641, 109529, 172654, 172668, 241842, 241920, 250574, 251369, 251436, 251459, 251834, 274673 and 274734 IC: 202, 574, 13053, 15975, 16829, 16834, 24072, 41680 and 41682
Field resistance/tolerance to pod shattering	EC: 34076, 39703, 107415, 232101, 241778, 250581, 250617, 251303 A, 251363, 251371, 251404, 251869, 250588, 251317, 251362, 251384, 251497, 254720 and Bragg IC: 96297 and 96356
High oil content (23–24 %)	EC: 37050, 37939, 39703, 76736, 95277, 95796, 102612, 107407, 107407, 110676, 110952, 113395 and 127512 IC: 9639 and 81835

minability/longevity, viz., IC 202, IC 574, IC 41680, IC 24072, EC 241920, EC 241842, EC 251369 etc. (Table 2). Seeds of such genotypes can be used to raise good plant stand even when stored at normal room temperature.

Number of seeds per pod and 100-seed weight are considered as yield contributing characters. The genotypes EC 172665, EC 250581 and EC 251528 had 3-4 seeds per pod whereas EC 39755, IC 96416 had the highest seed weight (44.4 g/100 seeds). Other genotypes ranged from 15-28 g per 100 seeds (Table 2). Commercially grown cultivars generally have 40 per cent protein and 20 per cent oil. Genotypes for high oil content were identified, having 23-24 per cent oil content (Table 2). Guodong and Jingling (1989) reported that the landraces in certain region of Heihi Prefecture and Songhuajiang Prefecture (China) had a higher protein content and the landraces in Suihua, Nunjiang and Hejiang Prefectures had higher oil content. Extent of yield loss due to pod shattering in soybean varied from negligible to as high as 90 per cent depending upon the time of harvesting, environmental conditions and the genotype. (Tiwari and Bhatnagar, 1988). In the present study, most varieties were found susceptible to pod shattering. However, a few accessions e.g. EC 34076, EC 39703, EC 107415, EC 232101, EC 251303-A, EC 251317, EC 251497, IC 96297, IC 96356 showed better resistance to shattering.

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SUGARCANE GERMPLASM COLLECTION IN MANIPUR AND MEGHALAYA

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One hundred and seven clones of Saccharum and related genera, Erianthus, Naranga, Miscanthus, Imperata, Neyrudia and Phragmites were collected from Manipur and Meghalaya. Variability in plant height, diameter and leaf type was observed.

North eastern India bordering Myanmar (Burma) and China is one of the major centres of diversity for *Saccharum* spp. and allied genera. Efforts to collect *Saccharum* germplasm from these areas began in 1950s with the launching of Spontaneum Expedition Scheme (SES), by the Indian Sugar Committee, for collecting wild *Saccharum* germplasm from different parts of the world. However, North eastern states were not adequately covered under SES. Efforts were renewed after three decades by Sugarcane Breeding Institute, Coimbatore, to explore and collect *Saccharum* germplasm from North eastern states before they become totally extinct. During the period from 1981-1985, four expeditions were organized by Sugarcane Breeding Institute under NBPCR National Exploration programme, New Delhi in the states of Bihar, Sikkim and Arunachal Pradesh and a total of 637 clones were collected and added to the World collection of sugarcane germplasm (Sreenivasan *et al.*, 1982, 1984, 1985; Sreenivasan and Palanichamy, 1985). The collection from Manipur and Meghalaya is a continuation of this programme.

Existence of abundant variability for *S. spontaneum* and *Erianthus* spp. in these regions had been already reported (Panje, 1951, 1953). Under SES, collections were made from both these states during 1951. Two *S. spontaneum* clones were collected from Manipur, one from Lok Tak and

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the other from Kangchup. From Meghalaya, 4 clones of *S. spontaneum*, one clone of *E. fulvus*, two clones of *E. arundinaceus* and one each of *E. longisetosus* and *Sclerostachya fusca* were collected. The areas explored were Cherrapunji, Shillong peak, Nungpoh and Umsaw. The present expedition was organized by Sugarcane Breeding Institute in collaboration with National Bureau of Plant Genetic Resources New Delhi during October, 1989 in Manipur and Meghalaya. More emphasis was given for collection from Manipur, because of the inadequate coverage of the State during the earlier expeditions and a possible commonness with the flora of Myanmar, particularly along the common rivers. The time of the expedition coincided with the peak flowering of *Saccharum* and related genera in this area.

SAMPLING AND COLLECTION METHODS

Collection routes were fixed based on the availability of species diversity. Collections were made from forest margins, open clearings, agricultural lands, river banks and hill slopes. Efforts were made to make the collections as representative as possible. Distinctive forms of tall, broad leaved, *S. spontaneum* were collected. Dwarf and medium tall forms which were much more frequent, were carefully sampled to avoid duplication. In *Erianthus*, collection of cane forming types were given more emphasis. Besides, clones possessing specific attributes like tolerance to waterlogging were also collected. Healthy stalks were collected in case of *S. officinarum*. Stalks were cut into 3 budded setts for packing and transport. Clumps were dug out for *S. spontaneum*, *Erianthus*, *Narenga* and *Imperata* spp. The collections were described on the spot for habit and all other morphological and flowering attributes. Besides information on altitude, habitat, plant association, soil type and topography were also recorded.

COLLECTION IN MANIPUR

A total of 85 collections were made (Table 1) from Imphal, Bishenpur, Churachandpur, Tamenglong and Ukhrul districts. Variability was limited for *Saccharum* germplasm in Imphal valley, which represent most of the cultivable land area of the state. Three distinct morphotypes of *S. spontaneum* were present in the valley. Tall, broad leaved forms were seen in semi-cultivated state in agricultural lands, being used for reinforcement in house construction. Some of them were mildly sweet forms growing to nearly 6m height and having about 2.5cm thick stalks. Dwarf, narrow leaved forms were frequent along paddy fields. Medium tall forms with broad leaves were also seen in the district. *S. officinarum* was in cultivation, in many parts of Imphal district. Four distinct varieties were found; red, yellow, green and one being striped types. Both dwarf and tall forms of *S. spontaneum* were present in Bishenpur district. Some of the tall forms were over 6m in height with 2.5cm thick stalks. Around Moirang, tall *S. spontaneum* forms were seen growing in partially submerged condition. The entire stretch from Imphal

to Churachandpur did not show any appreciable variation in topography or in elevation. The species diversity also was more or less similar upto Churachandpur except that *Narenga porphyrocoma* has frequent distribution after Moirang towards Churachandpur. Beyond Churachandpur, towards Lamja, the topography changes as elevation increases and dense vegetation and thick forest growth is encountered in this area. *S. spontaneum* and *Narenga porphyrocoma* were well distributed here along river banks and forest fringes, while *E. longisetosus* was found on hill slopes and relatively drier locations. Collections were made from Tolnum, Mata, Mualtam, Lamja and Nu kanang. One clone of *N. fallax* could be collected from Nu kanang. Lok Tak is one of the largest fresh water lakes in the north east. The area around Lok Tak was surveyed but variability for *Saccharum* germplasm was lacking. Along the banks of the lake, two distinct *S. spontaneum* forms were found to be growing in partially submerged condition. One clone of *Erianthus* also could be collected from Thanga village along the lake. Tamenglong district had a moderate distribution of *S. spontaneum* and related genera, especially at altitudes beyond 1000m. *S. spontaneum* was found freely growing in dry hill slopes, moist slopes as well as along river banks and other water sources. Tall forms of *S. spontaneum* were totally amiss in this area. Most of *S. spontaneum* forms found were dwarf to medium forms, the height never exceeding 2.5m. *E. procerum* was found in dry as well as moist habitats while *E. longisetosus* was found mostly on dry hill slopes

Table 1. List of sugarcane germplasm collected from Manipur and Meghalaya

Species	No. of accessions collected from		
	Manipur	Meghalaya	Total
<i>Saccharum officinarum</i>	5	—	5
<i>Saccharum spontaneum</i>	47	8	55
<i>Erianthus spp./hybrids</i>	4	1	5
<i>Erianthus fulvus</i>	—	3	3
<i>Erianthus procerum</i>	6	—	6
<i>Erianthus longisetosus</i>	5	—	5
<i>Narenga porphyrocoma</i>	10	3	13
<i>Narenga fallax</i>	3	1	4
<i>Neyraudia sp.</i>	—	1	1
<i>Imperata cylindrica</i>	4	2	6
<i>Phragmites karka</i>	1	—	1
<i>Miscanthus nepalensis</i>	—	3	3
Total	85	22	107

and even on hills of conglomerate rocks with little soil cover. *N. porphyrocoma* and *Imperata cylindrica* were also found in the area.

Maximum diversity for *Saccharum* and related genera was found in Ukhrul district. Again variability was high in the hills beyond 1000m. and *S. spontaneum*, *Erianthus* spp. and *N. porphyrocoma* were well represented in the district. Variability for *S. spontaneum* from narrow leaved dwarf forms (0.3m) to broad leaved tall forms growing to over 6m were present in the district. They were found in all habitats, along road sides, agricultural lands, hill slopes, among forest vegetation, on rock slopes and even in flooded condition. Dwarf forms were found to colonise hill slopes and river banks. Broad leaved forms were found in isolation or in association with plants of other genera. One broad leaved *S. spontaneum* form collected from Hundung, from dense forest growth was 6.36m tall. *E. longisetosus* was frequent on hill slopes and dry terrains and some of them were heavily branched and with number of arrows. Very huge forms of *Phragmites karka* were found in Ukhrul. Other grasses found in association were *Cymbopogon* and *Imperata* spp. *S. officinarum* was being cultivated in home gardens at Lambut (1510m) and Ukhrul (1820m).

SPECIES DISTRIBUTION AND VARIABILITY IN MANIPUR

Collections were made from altitudes ranging from 800m to 1820m. Diversity was found to be higher at altitudes beyond 900m. Of the 85 clones collected from Manipur, 40 came from Ukhrul district alone, which was found to be rich in diversity for *Saccharum* complex. *S. spontaneum* had the maximum diversity and was well distributed throughout the state. *N. porphyrocoma* also was well distributed, but variability for the species appeared to be limited. *S. officinarum* was in cultivation in Imphal district and in a limited scale at Ukhrul. Other species of interest found in the state were *E. longisetosus* and *E. procerum* and certain *Erianthus* forms of hybrid origin. *Erianthus filivus* and *Miscanthus* were conspicuously absent in the areas visited.

Variability in general was very high for *Saccharum spontaneum* (Table 2). From very small forms (0.30m) to very tall (6.36m) were found in the state. Three *S. spontaneum* clones were collected which had stalk heights of over 6m. Stalk diameter ranged from 0.4cm to 3cm. All *S. officinarum* clones collected were of thick forms (3 to 4 cm) with robust growth.

Table 2. Variability for stalk height in Manipur collections

Species/genera	Plant height							Total No. of clones
	Less than 1m	1-2 m	2-3 m	3-4 m	4-5 m	5-6 m	6-7 m	
<i>S. spontaneum</i>	14	14	7	5	4	—	3	47
<i>S. officinarum</i>	—	—	—	5	—	—	—	5
<i>Erianthus spp/hybrids</i>	—	—	2	1	—	1	—	4
<i>E. longisetosus</i>	1	—	1	3	—	—	—	5
<i>E. procerum</i>	—	—	1	5	—	—	—	6
<i>N. fallax</i>	—	2	1	—	—	—	—	3
<i>N. porphyrocoma</i>	—	5	3	—	2	—	—	10
<i>Imperata cylindrica</i>	4	—	—	—	—	—	—	4
<i>Phragmites karka</i>	—	—	—	—	—	—	1	1
Total								85

COLLECTION IN MEGHALAYA

Collection in Meghalaya was restricted to Barapani, Umsaw, Upper Shillong and Cherrapunji areas and a total of 22 clones were collected (Table 1). There was extensive distribution of *E. hookeri* along the hill slopes surrounding Barapani lake, but none of the clones were in flowering. *S. spontaneum* and *N. porphyrocoma* also had wide distribution in the area. Along the fringes of the lake, *N. fallax* could be located, but this species was sparsely distributed, otherwise. *Neyraudia* and *Phragmites* were found in association with *Narenga*. There was extensive distribution of *Miscanthus nepalensis* and *E. fulvus* from Upper Shillong to Shillong peak, beyond 1700m altitude. Large populations of these two species were found in close association along the hill slopes of upper Shillong towards Shillong peak and also upto some 15 km beyond Upper Shillong towards Cherrapunji. *Imperata* was closely in association with *E. fulvus* in some areas. *S. spontaneum* was seen along river banks occasionally.

Approaching Cherrapunji, the vegetation appeared to be poor and *Saccharum* spp. were not frequent. One natural hybrid, possibly of *S. spontaneum*, was found in a semi-cultivated state in old Cherrapunji. The plant was about 20 feet tall with erect habit and broad leaves. Stalks were thick and hard with brownish patches and resembles *S. robustum* to some extent. Beyond Cherrapunji, towards Shylla, *S. spontaneum* were frequently seen.

SPECIES DIVERSITY IN MEGHALAYA

Collections were made from altitudes ranging from 250m to 1800m in Meghalaya. Barapani area had extensive distribution of *E. hookeri* and *N. porphyrocoma* but variability appeared to be limited. *N. fallax* is present in the area. *Miscanthus nepalensis* and *E. fulvus* were found only at altitudes beyond 1700m in Upper Shillong and nearby areas and variability appeared to be low. Most of these forms were less than 1m tall. One clone, possibly a *S. spontaneum* hybrid, collected from Cherrapunji was interesting with features resembling *S. robustum*.

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GENETIC DIVERGENCE IN SOME FLOWERING CLONES OF *SACCHARUM BARBERI* AND *S. SINENSE*

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Nine clones of S. barberi and four clones of S. sinense were evaluated to study genetic divergence. The clones were grouped into four clusters on the basis of 13 quantitative characters subjected to multivariate D² analysis. Hybridization among clones from cluster IV and II, IV and III; and I and II having the maximum inter-cluster distances may yield better recombinants for various characters.

Saccharum barberi and *S. sinense* clones were under cultivation in India and China before the advent of hybrid varieties of sugarcane. The clones are low yielding, but hardy, tolerant to environmental stresses and major diseases and have fairly good sucrose content. The clones of these species have received little attention after the initial use due to poor flowering and sterility. The present investigations aim at the evaluation of some flowering clones of *S. barberi* and *S. sinense* to study the pattern of genetic divergence for further improvement of the crop.

MATERIALS AND METHODS

The experimental material comprised nine clones of *Saccharum barberi* and four clones of *Saccharum sinense* which flowered at Coimbatore and/or Cannonore. The clones were evaluated in a randomised block design with two replications at Sugarcane Breeding Institute, Coimbatore during 1989-90. The clones were planted in a row plot of 6m length spaced 90cm apart.

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Twenty three-budded setts were planted at equal distance. Sample juice analysis was done at 10 month crop age and the trial was harvested at 12 month crop age. Data on 13 quantitative characters of cane yield and juice quality were recorded. The data were subjected to Mahalanobis D^2 analysis and the clones were grouped in various clusters by Tocher's method (Rao 1952).

RESULTS AND DISCUSSIONS

Significant differences were observed among the genotypes for all traits, except juice extraction per cent and purity per cent indicating the scope for isolating better parents which may produce elite progenies. Performance of clones with respect to cane yield and juice quality traits is presented in Table 1. The clones **Khakai** and **Manjuria** were significantly superior to general mean 3.96kg for sugar yield (per plot). Four clones, viz., **Kansar**, **Khadya**, **Katha** and **Manjuria** were better to general mean (62) for number of millable canes (NMC). For juice quality only the clone **Manjuria** was significantly superior to general mean.

Thirteen clones were grouped into four clusters (Table 2). Cluster I comprised nine clones. Two clones, viz. **Manjuria** and **Nargori** formed individual clusters (III and IV). Cluster means indicated that cluster III has the highest sugar yield per plot whereas cluster IV was the poorest (Table 3). Cluster II was the best for cane yield, NMC, cane length and germination percentage. For quality traits also cluster III was the best, whereas cluster I was the poorest.

Intra-cluster distances ranged from 0 to 52.92. The highest value was observed for cluster I. Cluster II and III were quite close to each other. Inter-cluster distances varied from 91.85 between clusters II and III to 236.29 between clusters II and IV (Table 4). Remarkably high inter-cluster distances were observed between cluster IV and other clusters. Therefore, the hybridization among the clones from IV and II, IV and III, I and II might enhance the variance of the progeny populations. The use of genotypes from various clusters with the maximum diversity has been emphasised by many workers in sugarcane (Singh and Singh, 1981; Gill and Tripathi, 1983; Hooda *et al.*, 1990). This would enhance variability whereby making selection more efficient. Utilization of such improved clones of the species in breeding would seem appropriate in achieving better and quicker gains.

Table 1. Performance of 13 flowering clones of *S. barberi* and *S. sinense*

Clones	Cane yield/ plot (kg)	NMC ¹	Cane dia- meter (cm)	Cane length (m)	Single cane weight (kg)	Juice extra- ction	Brix (%)	Sources (%)		Purity	CCS ² (%)	Sugar yield/ plot (kg)
								10 months	12 months			
Agoul	36.3	77	1.83	1.40	0.46	48.7	14.63	13.83*	11.78	80.14	7.78	2.60
Kansar	61.0	148*	1.3	1.80	0.41	48.2	19.16	13.19	15.88	82.93	10.64	6.48
Khadya	24.2	111*	1.35	1.60	0.22	33.2	17.76	10.35	13.34	76.59	8.45	2.01
Khakai	65.3	77	2.58*	1.68	0.85*	61.3	18.20	11.82	15.75	86.57	10.78	7.05*
Katha	64.3	138*	1.80	2.10*	0.46	43.2	17.29	13.09	13.21	75.98	8.45	5.01
Kheli	56.1	79	2.20*	1.98*	0.71*	46.5	15.33	8.08	10.82	70.36	6.58	3.72
Lal Khadi	46.7	90	2.00	1.78	0.52	47.9	15.08	7.90	10.36	68.58	6.18	2.87
Manjuria	54.3	112*	1.85	1.68	0.47	58.6	20.71	14.96*	18.61*	89.93	12.98*	6.98*
Nargoi	13.5	42	1.35	1.58	0.32	50.0	18.85	13.21	16.01	84.86	10.86	1.43
Pansahi	40.3	90	1.50	1.70	0.47	54.2	13.76	10.23	10.19	73.53	6.40	2.45
Pathri	28.8	61	2.12	1.58	0.47	52.8	19.56	15.16*	17.35	88.76	12.03	3.45
Uba Seed-ling	33.3	73	1.98	1.48	0.45	57.8	18.30	14.47*	16.16	88.37	11.18	3.77
Uba White	39.2	90	2.03	1.53	0.44	58.0	16.50	10.77	13.53	81.81	9.02	3.65
G.M.	43.3	62	1.87	1.68	0.48	50.8	17.32	12.08	14.08	80.65	9.33	3.96
C.D.	26.0	35	0.32	0.24	0.09	NS	3.45	1.54	4.44	NS	3.62	2.70

*Significantly superior to general mean (G.M.) at P = 0.05

¹NMC : Number of millable canes²CCS : Commercial cane sugar

Table 2 Distribution of 13 *S. barberi* and *S. sinense* clones in different clusters on the basis of cane yield and juice quality characters

Cluster	No. of clones	Clones
I	9	Agoul, Khadya, Kheli, Khakai, Lal Khadi, Pansahi, Pathri, Uba-seedling, Uba white
II	2	Kansar, Katha
III	1	Manjuria
IV	1	Nargori

Table 3. Cluster means for 13 characters in *S. barberi* and *S. sinense*

Cluster	Sugar yield/ plot (kg)	Cane yield/ plot (kg)	CCS %	Purity (%)	Sucrose (%) 10 Months	12 Months	Brix (%)	Juice extra- ction (%)	NMC	Cane dia- meter (cm)	Cane length (m)	Single cane weight (kg)	Germi- nation (%)
I	3.51	41.1	8.71	79.41	11.40	13.25	16.57	51.2	83	1.95	1.64	0.51	70.2
II	5.75	62.7	9.55	79.46	13.14	14.55	18.23	45.7	143	1.77	1.95	0.44	82.1
III	6.98	54.3	12.98	89.93	14.96	18.61	20.71	58.6	112	1.85	1.68	0.47	76.7
IV	1.43	13.5	10.86	84.86	13.21	16.01	18.85	50.0	42	1.35	1.58	0.32	18.0

Table 4 Average intra and inter-cluster distance (D) values on the basis of cane yield and juice quality traits in *S. barberi* and *S. sinense*

Clusters	I	II	III	IV
I	52.92	188.72	101.26	145.24
II		17.83	91.85	236.29
III			0.00	234.49
IV				0.00

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GRAIN AMARANTHS IN THE HIMALAYAS

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*Periodic attempts have been made to trace the history and origin of grain amaranth by different research workers but still very little is known. Some more information on *Amaranthus hypochondriacus* L., *A. cruentus* L. and *A. caudatus* L. has been added based on published work and folklore information gathered in India. There are approximately 25 species of *Amaranthus* available in the Asian region. Four Sanskrit names (Rahadri, Rajagiri, Rajashakini and Tandulya) are available in the old literature. The fossil records of pollen have been documented in several excavations in India from Holocene and late Pliocene periods. Enormous genetic diversity and concentrations of the crop in the Himalayan region unlike peninsular India, its uses and prohibition in different rituals, large number of vernacular names of medicinal and culinary preparations and the amount of genetic diversity in grain amaranths as observed in Himalayas would indicate the greater likelihood of spread of the crop in India from that region in eighth century. Their direct and indirect evidences of the antiquity of the crop in India suggested that possibly grain amaranths were prevalent in south Asia from time immemorial.*

Amaranth is one of a few economic plants of great food value bestowed by nature, with multiple uses. This is a favourite of poor masses who sustain for their food on marginal lands. It is highly nutritious and has a capacity to wipe out malnutrition in the third world (Anon. 1984). The organoleptic taste of leaves and grain food products has been found to be excellent (Grubben and Sloten, 1981). Grain amaranth can withstand adverse weather changes particularly severe moisture stress, thereby showing better potential (Joshi and Rana, 1991). It can be grown in diverse agro-climatic conditions, high rainfall areas to as low as 400 mm per year from sea shore to high altitudes and is most suitable crop for sustainable agriculture (Joshi, 1991).

In view of its great economic and nutritional importance coupled with wide adaptability, the National Bureau of Plant Genetic Resources, Regional Station, Shimla initiated collection, evaluation during the past two decades and consequently over 3,000, collections were made from wide agro-ecological regions of Himalayas as well as from exotic sources. Based on studies carried out on the germplasm survey and collections from Himalayan region from 1979 to 1991, some more information on history of grain amaranth and their ethnobotany has been discussed.

DOMESTICATION OF THE SPECIES

The origin of various species of cultivated amaranths is not easy to trace because the wild ancestors are pantropical cosmopolitan weeds. Amaranths are presently cultivated as pseudocereals in both old and new world. The regions of origin and domestication of the grain amaranths were once controversial. However, Sauer (1950, 1967) has presented several lines of evidence, pointing to the New World as the Centre of origin and domestication. Working independently, Hungiker (1952) arrived at the same conclusion. The three grain amaranth species, i.e., *Amaranthus hypochondricus*, *A. cruentus* and *A. caudatus* were domesticated prehistorically in the highlands of tropical and sub-tropical America. However, the crop has declined to a vanishing relic in its home land as more amaranth grain is now produced in Asia, especially in India, than in the Americas. According to Sauer (1967), amaranths were widely distributed through the temperate and tropical regions of the world before man domesticated them or converted some of them into cosmopolitan weeds. Sixty species were native to the New World and about 15 to the Old World and Australia. Most of them were pioneer annuals of naturally open habitats; mountain and desert canyons, river banks, lake shores, tidal marshes, and ocean beaches. Producing abundant seed, widely dispersed by water and birds, they survived by constant colonization of sites with disturbed soil, full sun and little competition, long natural selection for such a way of life; preadapted certain of the species for survival in habitats which were drastically disturbed by man. The domestication of amaranths for use as pot herb took place only in Asia (Sauer, 1967). A variety of cultivated races assigned to *A. lividus* and *A. tricolor* which are common pot herb in eastern and southern Asia have been subsequently introduced into New World. *A. tricolor* might have originated in India and have spread to neighbouring countries, by traders, Buddhist monks and Muslim invaders.

In his 1950 survey of the history and classification of grain amaranth Johanathan Sauer suggests a number of areas in the ancient literature

of the old world which have not been searched for evidence of grain amaranths. Ames (1939), Vavilov (1949), Darlington & Janaki-Ammal (1945), Merrill (1950), De Candolle (1983) and Hooker (1985), based on several observations, concluded that grain amaranths have been cultivated in South Asia from time immemorial and probably originated there. *A. hypochondriacus* and *A. caudatus* are the two main species grown throughout the prevalent regions of Asia stretching from Manchuria, interior of China and across the Himalayas upto Afghanistan and Persia (Atkinson, 1891). The 10th Century records of grain amaranth in China (Sauer, 1950) provide some evidence of its great antiquity in Asia. Grain amaranths have been introduced to India's Malabar Coast by early Portuguese traders from Brazil (Merrill, 1945) after 1500 A.D or probably may have been introduced from China through land route. However, observations on the history, distribution, crop diversity, fossil records, Sanskrit names, large number of vernacular names, a variety of uses and ethnobotanical evidences etc. suggested that grain amaranths have probably originated the Himalayas, may have co-evolved as in maize, or simultaneously originated at more than one sites.

TAXONOMY

In India, ten species of Amaranths i.e. *Amaranthus tricolor*, *A. dubius*, *A. melancholicus*, *A. gangeticus*, *A. hypochondriacus*, *A. cruentus*, *A. caudatus*, *A. spinosus*, *A. hybridus* and *A. retroflexus* are found. Including Australia, there are 25 species occurring in this region of Old World as against a total of 60 species found in the New World (Willis, 1973). Taxonomically all the grain amaranths cultivated in the Old World are indistinguishable from those cultivated in the New World. Not only in terms of species but also in terms of sub-specific entities, the available Old World specimens represent nothing but a small sample of diversity present in the American grain amaranths. The entire Asiatic pot-herb group is easily distinguishable from the grain group by a few important characters, such as number of stamens, number of tapels, and shape of the tapels. Few of these Asiatic species are even superficially similar to the grain amaranths, for one thing none of them has a branched terminal inflorescence (Sauer, 1950).

While classifying the germplasm collected from wide agro-ecological regions of Himalayas, Joshi (1981) observed that the present taxonomical grouping is inadequate. It needs further detailed studies because introgression and aneuploidy in the natural populations have played a crucial role to generate a taxonomic complexities in the genus.

DIALECTUAL NOMENCLATURE

There are atleast twenty vernacular names given to grain amaranths in different parts of India, viz, *ramdana* in Bihar; *rajgira* in Deccan; *rajgara* in Gujarat; *anardana* in Eastern Uttar Pradesh; *chuka* in Bengal; *kalaghesa*, *chumera* and *ganhar* in Central India; *kelabagi* and *rajagira* in Maharashtra; *kiyan* in Kerala; *bustanfrej* in Kashmir; *seol*, *chaulai* and *sil* in Northern plains; *bathu* in Shimla; *siriara* in Kullu; *tulsi*, *dankar* and *kalji* in Kinnaur; *chua* in Kumaon hills and *marchu* in Garwhal Himalayas (Singh and Thomas, 1978; Joshi, 1983) indicating its great antiquity, ancient association and popularity in the tribal culture of India. The grain amaranth is locally known as *Siriara* in Kullu valley of Himachal Pradesh. This may have a similarity with the word Sierra Madra Occidentale of Mexico or from Sierra Norte of Peru which is abundantly found in the tropical highland of Mexico and in the Andean region of Peru (Hauptli, 1979 and Nabhan, 1979) or vice-versa. Likewise the vernacular name *chua* in the Kumaon hills of Himalayas has got a similarity with the word *Chihuhaa* of Mexico where roughly 65 per cent of the northern Tephan families are still cultivating *A. hypochondriacus* (Nabhan 1979) or *Quecha*, the name applied to cultivated amaranth in Peru (Kalinowski, 1987). In some parts of Nepal, it is called *murcha*, similar to *marchu* in Garwhal Himalayas in India.

In Chinese and Manchurian mountain regions, amaranth seeds are locally called *Tien-Shu-Tzi*, i.e, millet from heaven. Likewise in India the grain amaranth is locally called *ramdana* i.e, seed sent by God (Anon., 1984). This indicates its very ancient associaton with the culture of the Asian people.

ANCIENT MIGRATIONS AND RECORDS

Fossil records of amaranth/chenopod group of pollen have been observed from several areas in India (Sukko-tada in Gujarat and Diamabad in Maharashtra) from Holocene and late Pleistocene period. *Amaranthus* spp* recorded in Harappan civilization (Posschlo, 1982) also confirms its antiquity in the Indian subcontinent. On certain religious occasions and on fast days, grain amaranth was the only permitted food for consumption by the people (Singh, 1961; Joshi, 1981). Its use during *Shradha* (ritual ceremony to mark death anniversary) is prohibited in India; the custom is usually practiced by higher castes.

Johannessen and Anni (1985) discovered that grain amaranth being used in Bhutan as the main ingredients in *tormas* (ceremonial conical shaped figures of dough) which are made once a year on the celebration

*The fossil records of pollen as evidence of antiquity of grain amaranth cultivation appear to rather indirect in view of the difficulty in distinguishing grain amarnath pollen from vegetable amaranths and also from chenopods.

of Guru Pamasambhava (who is thought to have introduced Buddhism to Bhutan from India in the 8th Century at a monastery called Gomkhora in eastern Bhutan) can be considered as an indication of the introduction of amaranth from India to Bhutan.

USES

The green leaves when tender are used as vegetable. The tender stem is used in vegetable curry like drumstick. The grains after roasting and sometime grinding are used in different culinary preparations, such as sweet porriadge (*kheer*), pudding, *chappati*, sweet ball (*Ladoo*), *Parantha* and crisp *Pakora* in Himalayas, Alcoholic drinks is also prepared from fermented seeds. The crop is grown on the border of maize field to ward-off bird damage to maize cob (due to colour effect of red inflorescence types). When rock boulders are heated with the smoke of dried stem of amarnath and the decoction of horsegram, it is considered to break big rocks just like explosives. In certain areas of Himachal Pradesh (Radhu, Khanag, Kullu, and Pangi), the grain stocks are used for meat and apple fruit preservation for 4-6 months. It is reported by them that the meat remain fresh for one and half month and becomes more tastey whereas apples remain farm fresh for 4-6 months when merged in grain-bins of amaranth. Amaranth is considered delicious, nutrititous and sumptuous food when mixed with finger millet flour in Uttrakhand Himalayas.

Its food and medicinal uses were indicated since the ancient vedic civilisation (Shastri, 1961). It has been mentioned that the grain amaranth leaves and seeds are laxative, soporific and narcotic, and improve appetite, useful in biliousness, *kapha*. The plant is used for purifying the blood, and in piles, and also diuretic in strangury. It is given in scrofula and applied topically on scrofulous sores. Behari *et al.* (1986) reported that the species *A. viridis* is used as a pot herb and in treating snake bites. In Tamil Nadu and Kerala hills, the tribals use stem and leaf juice of *A. spinosus* in the treatment of kidney stones. In Uttarakhand Himalayas, people consider that the grain helps in curing the measels in children by bringing down the body temperature when they sleep over the spreaded grains on the bed. In Himachal Pradesh, it is considered that the decoction of grains is very effective in treatment of foot and mouth diseases of animals. However, excessive feeding of amaranth green to the cattle is considered to cause mouth and tongue ailment.

MIGRATION TO HIMALAYAS AND OTHER REGIONS IN INDIA

In the 6th Century A.D when Arab started invading India via Kashmir and Gujarat state, the simple, religious and non-violent people

from Gujarat, Rajasthan, Maharashtra and Madhya Pradesh started migrating to the safer and holy places and eventually took refuge in the Himalayas where they permanently settled. It may be emphasized that the present set-up of Kumaon including Garhwal Himalayas is a result of immigration of different people during the mediaeval period (Atkinson, 1974). The Chamba region of the Himachal Pradesh is the richest of all the epigraphical remain beginning from the 6th century A.D down to the last century (Ahluwalia, 1988). Another important copper plate has been found in Nirmand (Kullu) dating 6th century which was issued by Maharaja Samudrasen of Kullu (Hutchison and Vogel, 1933). While some of the people returned to their native place and probably they must have brought with them the seeds of grain amaranth as food from Himalayas. In Mehsana area of Gujarat state, it is still cultivated as one of the staple food crop and grown extensively. Since amaranths grow vigorously, resist drought, heat and pests and have a high reproduction rate (one plant produces more than 50,000 to 1,00,000 seeds and adapts readily to new environment), they got established in rest of the Indian region by way of pilgrimage. In the 9th century with the establishment of the holy shrine in North-west Himalayas by Adi Guru Shankaracharya, regular pilgrimage to these remote inaccessible areas increased. A large number of devotees visiting holy places from different parts of India needed food for long period of time and journey on foot which sometime took more than a year to and fro. People took amaranth seeds with them while returning. Since it is easy to carry and process, and a dual purpose crop used both the green and grain and the only permitted food for those who observe fast, its demand by devotees increased which probably promoted its intensive cultivation in the Himalayas and its marginal diffusion in rest of the country.

VARIABILITY AND CONCENTRATION IN HIMALAYAS

A great deal of variability and concentration of the crop is found in the Himalayas (Jain *et al.*, 1979; Joshi, 1981) unlike in peninsular India, particularly the coastal regions. This does not support the views of its sea route introduction by Portuguese, (Merrill, 1954). The amount of diversity in the crop with regards to plant height, branching behaviour, inflorescence shape, size and colour spiny and glabrous nature of bracts, lateral and terminal spikelet, branching pattern and their size, seed shape, size and color (7 forms) generated in the crops in Himalayas itself speaks of its long and ancient cultivation, (Joshi, 1983). The occurrence of 15 species of amaranth in Asia and 10 species particularly in the Himalayas together with the amount of genetic diversity observed in the Himalayas would indicate the origin, and the greater likelihood of spread of the crop in India and other Asian

countries, from this region rather from coastal part of India and from New World.

COMPARISON OF COLLECTION AND EVALUATION

A comparison of grain amaranth in India (Joshi, 1981, 1991) and in Central America (Hauptli *et al.*, 1979; Nabhan, 1979) indicate close similarity in the cultivated species distribution, evolution, variation pattern, cultivation practices and grain uses in two widely separated geographical regions of the world (Table 1). It has already been mentioned that grain amaranths (*A. hypochondriacus* and *A. caudatus*) were under cultivation in Old World before 1500 A.D (Singh, 1961; Joshi, 1983). This may indicate the independent and parallel origin and evolution of grain amaranth in Himalayas as well as in Central America in ancient time.

CONCLUSION

On reviewing the history of grain amaranths in Old World, it was observed that there are four Sanskrit names available in the literature (Kirtikar and Basu, 1918; Shastri, 1941). The fossil records of pollen have been found in several digs in India from Holocene and late Pleistocene period (Posschlo, 1982). There are approximately 25 species of *Amaranthus* available in the Asian region (Willis, 1973) with great deal genetic diversity in the Himalayas (Joshi, 1983). Its uses and prohibition in different rituals in India and Bhutan indicate its ancient association with culture of the people of Asia. Twenty vernacular names given to the crop in the Indian region, association with large number of uses of various culinary preparations and in medicines confirms ancient existence of the crop in this region. The migration and settlement of simple and religious people in the Himalayas in 6th century (The Malana village in Kullu district)* from the west coastal region and central part of India are the indirect evidences throwing a great deal of light on its independent origin than of pre 1500 A.D. introduction in Old World. Parker (1986) studied the ancient Hindu, Arabic, Chinese and Persian literature in order to find pre 1500 A.D. written evidence of grain amaranths in the Old World. In China, a book called *Ku Chin T'u Shu Chi Ch'en*, Vol. 65 by Ting-hsi Chiang in 1964 cites the historical reference which list

*An old villager of a remote village Malana in Kullu (Himachal Pradesh) revealed to the author that his ancestors led a nomadic life and carried with them the roasted seeds of grain amaranth locally collected from wild habitat. Some of the seeds undoubtedly were scattered and amaranth became established as a crop in one locality, now called Malana. Considering the place a holy one, where the roasted seed lot germinated, they permanently settled (probably in 7th century) and gave up their nomadic lifestyle. It appears that some of the unpopped seeds (which were not damaged) got germinated. Grain amaranth in the village has remained till today as their most cherished staple food.

Table 1. Comparison of distribution pattern and crop characteristics in grain amaranth from Himalayas and central America

Distribution pattern, crop characteristic & cultivation	New World & South America	Old World Himalayas
I. Species		
<i>A. hypochondriacus</i>	Distributed all the way from foot to high hills	Distributed all the way from foot to high hills
<i>A. cruentus</i>	Distributed in foot hills to mid hills	Distributed in foot hills to mid hills comparatively less adaptable to that of <i>A. hypochondriacus</i> confined to high hills
<i>A. caudatus</i>	Confined to high hills indicating specific physiological adaptation	Found in Himalayan region in rare frequency (Joshi 1981) showing similar evolutionary trends.
<i>Sp. novo</i> (A new genotype close to <i>A. edulis</i>)	Found in the population of amaranth field, rarely distributed (Hauptli, 1979)	
II Crop characteristics		
Seed colour	Seven seed colour types were collected by Hauptli, (1979) from Central and South America	seven seed colour types were collected from Himalayas (Joshi, 1981)
Inflorescence colour were	Similarity in inflorescence colour variation and other plant parts (Nabhan, 1979 and Hauptli, 1979).	Variation in inflorescence and other plant parts quite comparable (Joshi, 1983)
Hard threshability	Rare occurrence of non-circumscissile utricle in the population collected by Hauptli, 1979 from Central and South America	Rare occurrence of non-circumscissile utricles in the the population collected by Joshi, 1981 from Himalayas
III Cultivation pattern		
	Mixed cropping with maize and French bean which may have close ecological relationship generally followed in Central and South America	Mixed cropping with maize and French bean common practice in Himalayas indicating ecological relationship

uses of amaranths (Xian/Jian). The *Yiching* a book on geometry written in the 1st century B.C. uses the term Xian/Jian (amaranth). During Sung Dynasty (1101 A.D.), a book called the *Tu-ching pent t'sao* written by Shong Su about herbs mentions medicinal uses of herbs and the amaranth is cited in it. The Chinese sources clearly need further search and the reference cited by Sauer for the 10th century is very significant.

In India, *Garuda Purana* (roughly dated at around the 5th B.C) refers to *Tanduliya* and *Palankya* amaranth types which are anti-toxic and the *Brahmanda Purana* (which can be dated around 700-1000 A.D) states that 'all flowers equipped with sweet scent and beautiful fragrance are excellent. So also with *nadis* (Long tubes) as well as the yellow amaranth flowers.' In the *Sushruta Samhita* (5th B.C.) and Indian medicinal text which was originally written about two centuries before the birth of Buddha lists *Tandula* and *Tanduliyaka* as names for *Amaranthus* species. This book also lists *marisha* as the name of amaranth. Thus, the views of Merrill (1954) may not be tenable keeping in view the aforesaid observations and support. The views of the De Candolle (1833), Hooker (1985), Ames (1939), Vavilov (1949), Darlington and Janki Ammal (1945) that the grain amaranths have been cultivated in the South Asia from time immemorial and probably would have originated in the Himalayas may have to be upheld after further studies.

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GENETIC DIVERGENCE IN CLUSTERBEAN *CYAMOPSIS TETRAGONOLOBA* (L.) TAUB.

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Genetic divergence, as measured by Mahalanobis's D^2 statistic, was studied in 48 genotypes with a set of 11 characters contributing towards seed yield in clusterbean. Significant differences were observed for all the characters under study. Based on D^2 values, 48 genotypes were classified into nine clusters. The study also revealed that genetic divergence had less relevance to eco-geographical distribution of the varieties. Three genotypes viz., DSE 1J, Pusa Navbahar and HG 75 were most divergent and could be used in future breeding programme.

Genetically diverse parents in a breeding programme are known to produce high heterotic effects and consequently yield desirable segregants. Accordingly, the present studies were undertaken to estimate the genetic divergence in clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.) which has been recognised as an important dryland and industrial crop.

MATERIALS AND METHODS

The experimental material comprised 48 genotypes of clusterbean selected from the germplasm maintained in the Department of Plant Breeding, C.C.S. Haryana Agricultural University, Hisar. The details of these lines along with place of collection are given in Table 1. Sowing was done in randomised block design with three replications at C.C.S. HAU Research Farm, Hisar. The plot size was single row of three metres length spaced 45 cm apart. The data were recorded on days to first bloom, plant height (cm), branches per plant, clusters per plant, pods per plant, pods per cluster,

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Table 1. Clusterbean genotypes with their place of collection

Genotypes	Place of collection	Genotypes	Place of collection
Ageta Guara 111	Punjab	GCD-79	Gujarat
Ageta Guara 112	Punjab	GCD-80	Gujarat
Guara 80	Punjab	Kutch 8	Gujarat
CP 42	Delhi	FS 277	Haryana
CP 43	Delhi	GG1	Haryana
HG 7-3/P 10-1	Delhi	GG4	Haryana
HG 7-4/P 2-1	Delhi	HFG119	Haryana
Pusa Navabahar	Delhi	HFG156	Haryana
PIG85	Delhi	HFG 244	Haryana
PIG174	Delhi	HFG 257	Haryana
Suvidha	Delhi	HFG 258	Haryana
Durgapur Safed	Rajasthan	HFG 312	Haryana
Durgajay	Rajasthan	HFG 314	Haryana
DSE 1J	Rajasthan	HFG 381	Haryana
DSE2J	Rajasthan	HG-75	Haryana
RCC137	Rajasthan	HGS 182	Haryana
RGC 197	Rajasthan	HGS 143	Haryana
RGC 410	Rajasthan	HGS 47	Haryana
RGC 471	Rajasthan	HGS 57	Haryana
RGC 916	Rajasthan	HGS 58	Haryana
SPS 119	Rajasthan	HGS 95	Haryana
2470 (12)	Rajasthan	HGS 99	Haryana
D 39-1	Gujarat	HGS107	Haryana
GCD 78	Gujarat	79-1-5	U.S.A.

seeds per pod, 100-seed weight (g), seed yield per plant (g), days to maturity and harvest index (%). Mahalanobis D^2 statistic was used to measure genetic divergence (Rao, 1952).

RESULTS AND DISCUSSION

The analysis of variance revealed the significant differences among the genotypes for all characters (Table 2), indicating thereby that considerable amount of genetic variability existed for all the characters in the present material. The varieties were classified into nine clusters (Table 3). The maximum number of varieties were included in cluster I (33 varieties)

whereas, cluster V to IX had only single variety. The cluster I included varieties from all the sources which revealed that there was no association between clustering pattern and eco-geographical origin of the varieties. The earlier finding in clusterbean (Chaudhary *et al.*, 1975; Dass *et al.*, 1978 and Rao and Paroda, 1982) also revealed that geographical diversity is not

Table 2. Analysis of variance for various characters in clusterbean

S.No	Characters	Mean sum of squares			C.D (5%)	C.V. (1%)
		Rep.	Genotypes	Error		
1.	Days to first bloom	15.20**	102.57**	1.76	2.12	2.48
2.	Plant height (cm)	6.80	1681.78**	13.25	5.82	2.23
3.	Branches/plant	2.11	45.27**	0.80	1.43	15.24
4.	Clusters/plant	20.71*	375.90**	0.43	4.60	12.19
5.	Pods/plant	41.85	2754.97**	20.28	7.21	7.11
6.	Pods/cluster	0.41	4.93**	0.16	0.65	10.12
7.	Seeds/pod	0.94	0.84**	0.31	0.89	7.61
8.	Seed yield/plant	0.37	15.23**	0.46	1.08	14.27
9.	100-seed weight	0.02	0.33**	0.03	0.28	4.86
10.	Days to maturity	19.10	79.99**	8.50	4.66	2.22
11.	Harvest index (%)	0.38	35.65**	0.23	0.76	6.59

*,** Significant at 5% and 1% level, respectively

Table 3. Clustering of clusterbean genotypes

Cluster	No. of genotypes	Genotypes
I	33	HGS 47, HFG 312, HFG 314, HFG 258, HFG 119, HGS 182, GC1, HFG 257, HGS 99, HFG 156, HGS 95, HFG 381, HGS 107, FS 277, HFG 244, HGS 58, HGS 57, 79-1-5, RGC 137, DSE 2J, RGC 471, Durgapura Safed, RGC 916, RGC 197, RGC 410, HG 7-4, HG 7-3, CP 43, PLG 174, Suvidha, Kutch 8 and GCD 80.
II	5	Ageta Guara 111, Ageta Guara 112, CGD 78, SPs 119, and PLG 85.
III	3	Durgajay, HG-75, D 39-1
IV	2	HGS 43, DSE 1J
V	1	GGD79
VI	1	Guara 80
VII	1	GG4
VIII	1	Pusa Navbahar
IX	1	2470 (12)

necessarily related to genetic diversity. In this study, all the varieties were of Indian origin except 79-1-5 which was from U.S.A. Although clusterbean is believed to be of African origin, yet it has been domesticated in the north-western region of Indo-Pakistan (Hymowitz, 1972). It is likely that they have common genes. Therefore, varieties from Rajasthan, Haryana and Punjab may fall in one cluster. There has been considerable exchange of material from one place to another and most of the clusterbean genotypes in USA were introductions from India in 1903 (Hymowitz and Matlock, 1963). Therefore, 79-1-5 which is from USA also seem to have common genes.

Table 4. Average intra and inter-cluster (diagonal) D^2 value for clusterbean

Clusters	I	II	III	IV	V	VI	VII	VIII	IX
I	282.6	537.1	522.2	717.9	476.66	1483.5	1244.8	843.6	636.9
II		309.8	829.2	650.5	751.8	2138.1	1171.4	860.1	773.2
III			389.2	965.9	627.8	740.8	1611.6	1313.7	568.6
IV				220.9	1436.5	2248.2	1573.1	1860.9	834.5
V					0.0	1325.0	2000.5	987.6	900.7
VI						0.0	2909.3	2725.2	1815.0
VII							0.0	823.2	1713.1
VIII								0.0	1194.7
IX									0.0

The intra and Inter-cluster D^2 values in Table 4 indicated that intra cluster distance was higher indicating that environment of Hisar was favourable for the full expression of characters. earlier it was suggested that material studied be tested under favourable environmental conditions to study the genetic divergence (Upadhyaya and Murty, 1970; Jatasra and Paroda, 1978). The inter-cluster distance was maximum between cluster VI and VII (2909.3) followed by VI and VII (2725.2). The inter-cluster distance between cluster I and V was found to be the lowest (476.6). This suggested the close relationship between these clusters.

Table 5. Mean performance of divergent genotypes

Characters	Genotypes				
	Pusa	79-1-5	DSE 1J	HGS 43	HG 75
Days to first bloom	39.53	48.26	63.53	60.66	51.80
Plant height (cm)	134.80	66.40	161.20	153.26	159.23
Branches/plant	0.00	4.86	7.53	6.00	12.43
Clusters/plant	4.93	15.60	15.93	23.13	42.50
Pods/plant	7.73	47.74	51.00	42.13	122.40
Pods/cluster	1.20	2.86	2.73	2.86	6.60
Seeds/pod	7.73	7.00	6.26	8.26	6.88
Seed yield/plant(g)	0.33	1.73	5.93	14.33	8.16
100-seed weight(g)	4.07	2.80	3.51	3.52	3.53
Days to maturity	135.60	124.20	128.33	131.33	138.33
Harvest index(%)	1.70	7.04	16.28	16.23	7.68

Crosses among divergent parents are likely to yield desirable combinations. Therefore, a crossing programme should be initiated between the genotypes belonging to different clusters. The important points to be considered are (i) choice of the particular cluster from which genotypes are to be selected as parents and (ii) selection of particular genotypes from the selected group. The divergent genotypes along with their performance are presented in Table 5. The data from the table indicated that DSE 1J, Pusa Navabahal and HG 75 were quite divergent. In order to have high heterosis, these genotypes should be used in future breeding programme for high yield in clusterbean.

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COLLECTION, EVALUATION AND CONSERVATION OF RICES OF SOUTH ASIA WITH SPECIAL REFERENCE TO NORTH-EAST INDIA

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South Asian countries are rich in rice germplasm resources which are maintained under varied physiography, climate, topography and tribal cultures. IRRI has conserved nearly 50,000 accessions of rices from this region. Above 8000 diverse germplasms of rice were collected from north-eastern hilly region of India by different agencies. NBPGR Regional Station, Shillong further collected 1541 accessions of rice from this region between 1985-1990. Diversity in rice germplasm resources, conservation ex situ or in situ, exploitation of these resources in rice improvement programmes and potential use of wild relatives of rice from above region is discussed. Further, systematic collection from unexplored areas in the region is suggested.

The climate of south Asia is dominated by the monsoon. There are great climatic variations within the region. The countries of south Asia include some of the wettest regions on earth as well as both hot and cold deserts. Climatic variations range from the equatorial ocean climates of the Maldives to the most extreme mountain climates in the region of the Himalayas. The NE region of India records heavy rainfall during monsoon. The world's highest rainfall is received at Cherrapunji which recorded maximum of 12000 mm, annually. However, the rainfall range in the region is between 2000 to 12000 mm. Temperature varies with the altitude and ranged from 0°C to 37°C during a year (Kaul, 1981). The altitude varies from 50 to 5000 m. The staple food of the region is rice. Under varied physiography, climate, topography and ethnic races, rice cultivation has been a major practice for production of food in this region. Much emphasis has been laid on rice cultivation and to enhance its production, keeping in view the increased population.

The collection of rice germplasm from NE region of India is important. The region comprising the states of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura which represents 5 distinct agro-climatic areas of India. Sixty seven (67) types of ethnic tribes inhabit this region who dwell mostly in the hilly area. Due to these geographical variations and ethnic diversities, the region is endowed with a wide range of crop genetic diversity including rice. Further, proximity to other South Asian countries such as China, Bangladesh, Bhutan and Burma, has also helped in mobility, exchange as well as microspeciation of the rice germplasm. The selections made unknowingly by various ethnic groups inhabiting different altitude and climatic situations, who practiced different forms of primitive cultivation in different seasons, helped to preserve and contribute to the diversity of rice crop, especially the local landraces. Collection and conservation of these landraces of rice would be useful for posterity.

COLLECTION OF CULTIVATED RICE GERmplasm

All south Asian countries launched and expedited their crop germplasm collection programmes since seventies. Systematic survey of rice crop germplasm has been emphasized by most of the south Asian countries since then. Chang (1975, 1984) reported the status of conserved rice accessions in different south Asian countries. Table 1. substantiates the efforts of collection of rice germplasm by the representative countries till 1982.

Table 1. Rice germplasm collected by the different south Asian countries till 1982

Countries	Total accessions (approximate)	Estimated Total
Bangladesh	6,372	8,000 +
Bhutan	121	1,000 +
India	35,000	36,000 +
Nepal	1,670	1,500 +
Pakistan	1,419	1,500 +
Sri Lanka	3,152	4,000

India leads in terms of rice germplasm collections and the estimated total. Paroda and Malik (1990) stated that about 50,000 landraces of rice are expected to exist in India. Considering the national and state collections together, a total of nearly 66,000 accessions have so far been collected. If about 50 per cent of these are duplicates, about 17,000 landraces of rice still remain to be collected. Systematic collection of rice germplasm especially from NE region of India have been made

sporadically and most of the collections were maintained at Assam Agriculture Department at Titabor, Karimganj. Before 1970, two national rice germplasm collection programmes were made in the region; Manipur (MNP) collection of 904 (1955-70), while Assam Rice Collection (ARC) conducted in between 1968-71, accumulated 6,630 accessions. Emphasis on rice germplasm collection was given only during 1967-72 under the ICAR/PL 480 scheme. The survey and collection of rice germplasm made by different workers is given in Table 2.

Table 2. Area explored in the North-Eastern states of India (1960-1990)

Area covered	References
1. Arunachal Pradesh (5 districts); Nagaland (3 districts); Manipur (5 districts); Assam Hills & plains (6 districts); Meghalaya (3 districts) and Tripura (2 districts)	Sharma <i>et al.</i> , 1971, Sharma, 1982
2. Assam and Manipur	Padmanabhan, 1971; Krishnamurthy and Sharma, 1970
3. Sikkim	Kihara and Nakao, 1960; Arora, 1982
4. Nagaland	Kulkarni, 1962
5. Tripura	Sashikumar and Sardana, 1987
6. Arunachal Pradesh	Asthana and Mazumdar, 1981
7. Mizoram	Anonymous, 1986
8. All north-eastern States, except Sikkim	Hore and Sharma, 1985-1990

The NBPGR Regional Station, Shillong intensified the collection of crop germplasm from the region since 1985. According to Sharma *et al.* (1971), a total of 8003 diverse rices (mostly landraces) were collected from North eastern hilly region of India by different agencies. In addition, NBPGR Regional Station, Shillong further collected 1541 accessions of rice from this region (Table-3) during the period 1985-1990.

WILD SPECIES OF *ORYZA*

Very few systematic attempts of collection have been made by the south Asian countries. However, the occurrence of various wild species of *Oryza* in this region is given in Table 4. IRRI has collected almost all 22 wild taxa of *Oryza* spp. which are being maintained and used for various breeding programmes.

Table 3. Rice germplasm collected from NEH Region

States	Year						Total
	1985	1986	1987	1988	1989	1990	
Arunachal Pradesh	—	—	61	99	51	24	235
Assam	—	152	230	173	—	16	571
Manipur	—	—	—	—	10	—	10
Meghalaya	70	23	22	52	20	45	232
Mizoram	—	—	—	—	56	57	113
Nagaland	—	81	—	73	—	46	200
Sikkim	—	—	—	—	—	—	—
Tripura	—	48	—	94	38	—	180
Total	70	304	313	491	175	188	1541

Table 4. Occurrence of wild *Oryza* spp. in the south Asian countries

Countries	Species	Remarks
Bangladesh	i) <i>Oryza rufipogon</i>	—
	ii) <i>Oryza</i> Sp.	Floating rice without shattering habit
Bhutan	Unknown	Exploration and collection required
India	i) <i>Oryza nivara</i>	Thorough and systematic germplasm collection yet to be done
	ii) <i>O. officinalis</i>	
	iii) <i>O. rufipogon</i>	
	iv) <i>O. granulata</i>	
Sri Lanka	i) <i>O. officinalis</i>	Collection and conservation needed
	ii) <i>O. eichingeri</i>	
	iii) <i>O. rhizomatis</i>	
	iv) <i>O. rufipogon</i>	
	v) <i>O. nivara</i>	
	vi) <i>O. granulata</i>	
Pakistan	Unknown	Inventories of the collection not available
Maldives	Unknown	Exploration and collection needed.

In India, collaborative collection programme on wild *Oryza* species was taken from time to time. A collaborative team of CRR-IRAT-ORSTOM collected *O. nivara* and *O. officinalis* from western India in 1984 (Krishnamurthy and Sharma, 1987). Indo-Japanese team also surveyed the M.P., U.P. and Orissa states several times. NBPGR-IRRI joint exploration was also undertaken in the coastal mid-land and mountainous areas of Kerala (Vaughan and Muralidharan, 1989) and north Orissa, south Bihar and West Bengal (Malik and Vaughan, 1989). Seventy five and 132 samples, respectively, consisting of *O. officinalis*, *O. granulata*,

O. rufipogon, *O. nivara* and *O. malampuzhaensis* (a tetraploid form of *O. officinalis*) were collected during these two trips.

No systematic effort has so far been taken to collect the wild *Oryza* spp. in the NE Region of India, in particular. However, herbarium records provide the information that *O. nivara*, *O. rufipogon*, *O. granulata*, *O. meyeriana* and *O. officinalis* occur in foothills of Meghalaya and various low-lying areas of Assam, Manipur and Tripura.

DIVERSITY IN RICE GERMPLASM RESOURCES

The categorical report on the collected rice genetic diversity from each south Asian country is very scanty. However, an overview has been discussed by Vaughan and Chang (1980) on Bangladesh and Sri Lanka. Further Chang *et al.* (1982) briefed about the evaluation by workers in various National Rice Research Centers of Asia.

India's rices possess wide diversity in their morphological and physiological characteristics. They vary in duration from 60 to over 200 days and can grow in varied elevations from sea level to 2300 m; they are well adapted to different seasons of the year under both upland and deepwater conditions. At one extreme are the deep water rices growing in 5-6 m water and at the other rice grows with an annual rainfall of 650-700 mm. The landraces of rice collected from NE region show the following characteristics; (a) Mostly tall, leafy plant type, a few short statured (70-105 cm) with dark green, semi-erect leaves; (b) In the collections from high elevation of Arunachal Pradesh (2000-2500 m) plant and grains much resembled the Japonica type (Vairavan *et al.*, 1973); (c) Glabrous nature of leaf and husk was rare; (d) The Manipur collection showed a good range of agro-botanical characters; (e) Some varieties were glutinous; (f) Many of the collections were drought resistant types, particularly those from the Garo Hill district of Meghalaya and high elevation Jhum area of Nagaland; (g) Protein content varied from 6 per cent to 14 per cent, in some of these collections, whereas the amylose content varied from 0 to 29.5 per cent (Sharma *et al.*, 1971) and (h) Fourteen (14) cultivars of ARC collection, from NEH region show high levels of resistance to blast (IARI-5774, 5805, 5987, 6225, 6231, 6241, 6620, 7105, 7124, 10345, 10686, 10709, 10998, 11215). All these cultivars have also shown the resistance to gall midge and stem borer (Singh, 1973). Asthana and Majumdar (1981) evaluated 235 land races of rice and a catalogue was published for 56 characters. Various ecotypes have been identified with the help of microglychs. Sasikumar and Sardana (1987) evaluated 134 cultivars of rice collected from Tripura and found high degree of variation for different characters. Mehra and Arora (1982) remarked that collections made from north-eastern hilly region of India provided valuable genes for disease resistance, adaptability and grain types.

NBPGR Regional Station, Shillong screened 1075 accessions of rice varieties from the NE region. Morpho-agronomical characters were recorded for these accessions, following the rice descriptors of IRRI. Promising accessions have been recorded in the Annual Report of the station from 1985-1990. Further, 378 accessions of rice germplasm were screened against leaf roller (*Cnaphalocrocis medinalis*) incidence. The accessions showing less than 5 per cent leaf rolls per plant were NKG 211, C 2018, NKG 1177, C 1987, C 1942, C 1691, MMH 6/5, MMH 6/3, IC-89127, MMH 6/9, MMH 6/12, MMH 6/13, MMH 6/17, MMH 6/18, MMH 6/19, BD 103, IC-89632, BD 142, BD 150, IC-89433, KHD 8, DKH 54 and DKH 62. Fifty accessions of rice germplasm were screened for blast caused by *Pyricularia oryzae* Cav. in the uniform blast nursery against the check variety HR 12. Among these resistant accessions were BDS 7/360, NKG 1046, IC-81392, NKG 1009 and moderately resistant were NKG 1047, NKG 359, C 1981, BDS 7/383.

CONSERVATION OF RICE GERMPLASM

Status of genetic conservation of rice in south Asian countries as per (Chang, 1982) is given in Table 1. Further, details of rice germplasm conservation in the south Asian countries are given below.

Bangladesh : "Boro", "Aus", and "Aman", are the three common types and sown in different seasons in Bangladesh. The varietal diversities are pronounced. Practically, conservation in the form of assemblage of material began since 1911. The total rice germplasm accessions conserved is 6372.

Bhutan : The Bhutanese collection maintained at IRRI is represented by only 121 accessions.

India : Land under rice covers a vast array of ecological niches, and the diversity of rice germplasm both cultivated and wild is enormous. The conservation task for germplasm is handled by the NBPGR, New Delhi. The Rice germplasm holdings including other cereals is 35000. However, this include duplicates too. There is no genebank at present in the north-eastern part of the country and the NE region collections may also be referred to the long term repository at NBPGR, New Delhi.

Nepal: Thousands of rice varieties are grown in this small hilly country. The germplasm holding of rice (cultivar + landraces) is 1670 accessions.

Pakistan : The national collection is represented by a total of 1419 accessions. Out of these, 936 varieties have been kept in IRRI for long-term storage.

Sri Lanka : Although, Sri Lanka is a small island, it has marked variations in climatic, edaphic and hydrologic conditions. the island is a microcenter of varietal diversity. Wild rice species are widely distributed. The national collections hold 3152 accessions including 2516 landraces. Entries of about 2069 are now in IRRI cold storage as duplicate. The country has recently established its own gene bank.

Most of the wild species of *Oryza* occurring in Africa, Asia and Australia have been collected by IRRI and are being maintained for breeding utilization. The total size is around 1100 samples, many of which are heterogenous populations rather than pure strains (Chang *et al.*, 1982).

IN SITU CONSERVATION OF RICE GERMPLASM

Mostly the wild species of *Oryza* grow wildly in their respective habitat. Importance is gradually given to conserve it in the places where they are relatively safe. Vaughan (1989) has identified some areas in India and Sri Lanka where the wild relatives of *Oryza* species are conserved. Nasiruddin and Miah (1983) reported from Bangladesh that wild and weedy races of rice are mostly endemic in the deepwater rice areas especially in the central region of the country. For Bhutan, occurrence of various wild species of rice is insufficiently known. Nepal has got some varieties on floating rice in the eastern terai while wild rice species are concentrated mainly in the foothill areas. Nothing is known about the habitat preservation or so far the conservation of wild species of rice at lower altitude in Nepal where they are facing threatened. In Pakistan, Thatta district of Sind province is said to be a potential source of wild rice germplasm.

Both *ex situ* and *in situ* conservation of varieties, landraces and taxa of cultivated and wild species of rice in north-eastern region of India is practically nil. Systematic maintenance of this germplasm have not given much attention. However, a good number of collections of cultivated rice have been done by Assam Agricultural University, Jorhat; ICAR Research Complex for NEH Region, Shillong and NBPGR, Regional Station, Shillong and they are maintaining some of this material for their research purpose only. Since the establishment of NBPGR Regional Station at Shillong in 1985, systematic exploration, collection, characterisation of rice germplasms was done and the characterised germplasm sent regularly to its headquarters, at New Delhi for medium term conservation. With regards to *in situ* conservation of wild species, attention is yet to be given to both exploration and conservation aspects. Many areas are still inaccessible and unexplored and hence the status of wild rice species is necessary in this region in order to prioritise *in situ* or *ex situ* preservation/conservation of such materials.

USES

Most of the national centers have made profitable use of the dwarfing gene (sd-1) contributed by *Dee-geo-woo-gen* and varying numbers of the pest resistance genes derived from IRRI lines or IR varieties. In addition to this, through local screening and selection, several national centers have incorporated desired genes/characters for resistance or tolerance from other sources into their improved cultivars.

In south Asia, India alone has developed 322 varieties up to 1985. Out of these 208 varieties had one of the parent from exotic germplasm. IR-8 is alone involved in the development of 86 varieties. Extensive testing of indigenous germplasm was conducted against pests and diseases. The drought resistant N22 was used in breeding Bala. TKMG, which has multiple resistance to insects and diseases, became a parent of *Ratna*, *Saket-4*, *Parijat*, CR44-1 and their improved cultivars. TKMG (a strain of *Oryza nivara*) was extensively used at IRRI as a donor of disease and insect-resistance (Khush, 1977). The tungro virus resistance of PTB-10 has been bred in to improve cultivars such as *Jyothi*, *Rohini*, and *Triveni*. PTB-18 possessing multiple resistance has been widely used in India and at IRRI. FR 13A is an outstanding source for flood tolerance. Salt tolerant varieties like Pokkali and cold tolerant varieties like Himdhan were developed by the Indian breeders. Introduction of TN-1, Mahsuri, China-1039, IR-8 also become beneficial as sources of dwarfism in Rice Improvement programmes in India. Mahsuri of Malaysia and Leb Mue Nahng of Thailand were used to develop photoperiod-sensitive varieties.

In north-eastern states, the best varieties which still occupy a sizeable area are the selections from indigenous paddy material. Mention may be made of *Khonorulu* released in 1965 in Meghalaya for altitudes ranging from 1300-2000 m; *Nagaland Special* tolerant to blast, *Cercospora*, leaf spots, leaf roller, brown hopper etc., released in Nagaland; *Ngoba*, a selection from local material of Nagaland released in 1966 in Meghalaya; and *Pawn Buh* released in Mizoram. All these varieties possess tolerance to blast, *Cercospora*, and leaf scald, and also have tolerance to leaf roller, white and brown hoppers. Some indigenous varieties like *Manipuri* (in Assam & Meghalaya) are also popular among farmers and occupy top place among cultivars.

Rice breeders of Sri Lanka have used the outstanding levels of resistance to insects and tolerance to adverse soil factors found in their diverse germplasm. BG-400-1 derived from OB678/IR220/H4 has resistance to gall midge, blast and the bacterial diseases. BG 276-5 originating from OB678/2, BG34-8 is resistant to gall midge and bacterial blight. BW

100 selected from H501/Podiwee-A8/H5 has resistance to blast as well as to tolerance to iron toxicity.

In Bangladesh, rice breeders have made substantial progress in improving their deepwater rices from indigenous germplasm (Zaman, 1977). Two sister lines (BR 51-91-6 and BR 51-46-C1), both derived from IR20/IR 5-114-3 and selected by the Bangladesh Rice Research Institute, have been recommended for release in Burma and India for their promising yield performance.

POTENTIAL USE OF WILD RELATIVES

Six Asian wild species of *Oryza*, contributing some useful traits are presented in the Table 5. Extensive evaluation of wild *Oryza* spp. proved that these were valuable source of resistance to insect pest. Difficulties arise in recovering desirable progenies when the genomes of the parents differed in wild rice species. But, one strain of *O. nivara* (IRRI Acc.-101508), an annual Asian weed race, has been successfully used in incorporating resistance to grassy stunt virus into the semidwarfs (Khush, 1977).

Exploitation of wild rices for rice improvement has a positive impact in the production of hybrid rice. The necessary CMS line was obtained through a cross between *O. Sativa* var. *spontanea* with cultivated rice. Due to this phenomenon, the rice production could be enhanced by 24-30 per cent (Lin and Yuan, 1980).

FUTURE NEEDS

Systematic collection of rice landraces and its wild relative of rice from the unexplored regions of south Asia is to be intensified in order to evaluate and conserve them before they are lost for ever. Characterisation and evaluation of unscreened rice germplasm from NE region based on diverse ecosystem is needed for crop improvement work.

Ex situ conservation of landraces, cultigens of rice, and both *in situ* and *ex situ* conservation of wild relatives of *Oryza* (at generic as well as specific level) are necessary (Anon., 1982). The potentialities of wild *Oryza* species are astonishing and it may bring major changes to tackle various stress problems to obtain the desired rice production level. Plucknett *et al.* (1986) stated that wilds' plants have been under constant pressure from pathogens, pests, severe climates and unfavourable soils and have evolved myriad strategies for survival. It is this array of defensive traits, the product of millions of years of evolution, that is so valuable in Agriculture". Genetic resources of crops including gene pools of wild species as well as its cultivated forms are surely one of most important biological treasures (Chang, 1984). Harlan (1976) stated the multifaceted advantages and utility of wild relatives which

Table 5. Wild *Oryza* spp. of south Asian countries and their useful traits

Species	Genome group	Distribution	Useful traits
1. <i>Oryza nivara</i> Sharma & Sastry (<i>O. fatua</i> , <i>O. sativa</i> var. <i>spontanea</i>)	AA	South and south-east Asia and southern China	Resistance to grassy stunt virus and blast.
2. <i>O. officinalis</i> Wall. ex Watt. (<i>O. mala-mpuzhaensis</i>)	CC	South and south-east Asia, southern China, Papua New Guinea.	Resistance to BPH, WBPH and GLH (Heinrichs <i>et al.</i> , 1985).
3. <i>O. rufipogon</i> W. Griff. (<i>O. perennis</i> , <i>O. fatua</i> , <i>O. perennis</i> subsp. <i>balunga</i>)	AA	South and south-east Asia and southern China	Tolerance to stagnant flooding and acid sulphate soils.
4. <i>O. granulata</i> Nees & Arn. (<i>O. indanadamanica</i>)	Diploid	South and south-east Asia	Shade tolerant and possible adaptation to drought conditions due to its bulbous culm base (Vaughan <i>et al.</i> , 1991).
5. <i>O. rhizomatis</i> Vaughan	CC	Sri Lanka	Drought resistance (Vaughan <i>et al.</i> , 1991)
6. <i>O. eichingeri</i> A. Peter	CC	Sri Lanka	Shade tolerance and multiple pest resistance (Vaughan <i>et al.</i> , 1991).

can serve disease and pest resistance, wider adaptation and possibility of getting new cytoplasm, resistance to stress and, unpredictable characters.

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WILD RELATIVES OF GENUS *ALLIUM* L. IN HIMALAYAS

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The wild relatives of genus Allium have long been utilized as spices and condiments while occupying place in hill agriculture as a semi-domesticated crop. During an exploratory survey of plant genetic resources and related ethnobotanical study in the Himalayas, some of the wild Allium species such as Allium ampeloprasum L., A. ascalonicum L., A. auriculatum Kunth, A. cernuum Roth, A. carolinianum D C., A. chinense G. Don, A. consanguineum Kunth, A. humile Kunth, A. przewalskianum Regel, A. rubellum M. Bieb., A. semonovii Regel, A. tuberosum Rottl. ex Spreng., A. prattii Wright, and A. wallichii Kunth were collected. Besides widely cultivated plants like garlic, Indian leek, leek, nodding onion, onion and shallot etc., these Allium species are partially cultivated by the natives in their kitchen garden or backyards for green vegetables, spices and condiments. The field information on distribution, habitats, taxonomical characteristics and methods of utilization is highlighted to focus attention on these wild economic, useful genetic resources for future commercial exploitation.

Himalayan zone of India is represented by the states of Jammu and Kashmir, Himachal Pradesh, hilly regions of Uttar Pradesh and north-eastern region. It represents extreme climatic variations, topographic situations like undulating slopes, valleys and gorges. The Himalayas have provided several economically important plants used as food, medicines, spices and condiments etc. *Allium* is one of such species under present context. It is widely distributed in the temperate and alpine zones of the world, i.e., Europe, northern Asia, north-west America, the Altai mountains and middle Asia (Mani, 1978). It has about 500 species all over the world, of which thirty species are found in India (Santapau and Henry, 1973; Babu, 1977). So far, 15 species have been

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reported from temperate and alpine zones of Himalaya in India. Occasionally, a few of them are cultivated by the natives. Until recently despite their importance, little has been known about the taxonomy, utilization and cultivation of these wild *Allium* species. Therefore, an attempt is made in this paper to investigate these species of *Allium*, being native of Himalaya.

CULTIVATED AND SEMI-DOMESTICATED ALLIUMS

The best known six species as domesticated and extensively cultivated in the area, between the elevation of 300-3500 m are *Allium ampeloprasum* L. - Leek, *Hargandh*, *Sidhum*, *Vilaiti lahsoon*; *A. ascalonicum* L. - Shallot, *Dhun*; *A. cepa* L. - Onion, *Pyaz*; *A. cernuum* Roth - Nodding onion, Lady's leek, *Sikwa*; *A. sativum* L. - Garlic, *Lahsoon* and *A. tuberosum* Rottl. ex Spreng. - Indian leek, *Markua*.

The present survey on *Allium* species exploration, collection and ethnobotany is based on the guidelines and principles suggested by Jain and Rao (1977), Jain (1987) and Hawkes (1980). The information about habitat, uses, occurrence, abundance were gathered by repeated enquiries from the local folk and frequent field trips. Previous collections of *Allium* species have also been consulted from the Herbaria, such as Botanical Survey of India, Northern Circle, Dehra Dun (BSD), Taxonomy Branch, FRI, Dehra Dun (DD) and Department of Botany, Sh. H.N. Bahuguna Garhwal University Herbarium (GUH), Srinagar (U.P.). All the information from various field trips, folk people and herbaria are compiled. These wild *Allium* species are also maintained in the field gene bank and herbarium of NBPGR Regional Station-Bhowali, Nainital, U.P.

Allium is a bulbous herb with characteristic odour. Leaves variable, fistular, flat, elliptic, filiform or linear. Flowers white, yellow, red, rosy or purple, golden yellow, blue in capitata umbels, enclosed in 1-3 membranous spathes, stellate. Petals 6, free or fused into a corolla tube at the base. Stamens hypogynous or inserted on the perianth, filaments free or connate below, anthers oblong. Ovary 5-fused carpels, 3-chambered each with many ovules. Style 1, filiform. Fruit a capsule, 3-valved, rarely a fleshy berry, small. Seeds few, compressed, black. It is very close to the family Iridaceae, distinguished by its 6 stamens. It is also distinguished from Liliaceae by its superior ovary. Flowers are surrounded in the bud by a papery spathe or flowers born in branched clusters. On the basis of inflorescence characteristics, *Allium* is now placed in the commonly known Daffodil family, Amaryllidaceae (Hara *et al.*, 1978-82; Polunin and Stainton, 1984).

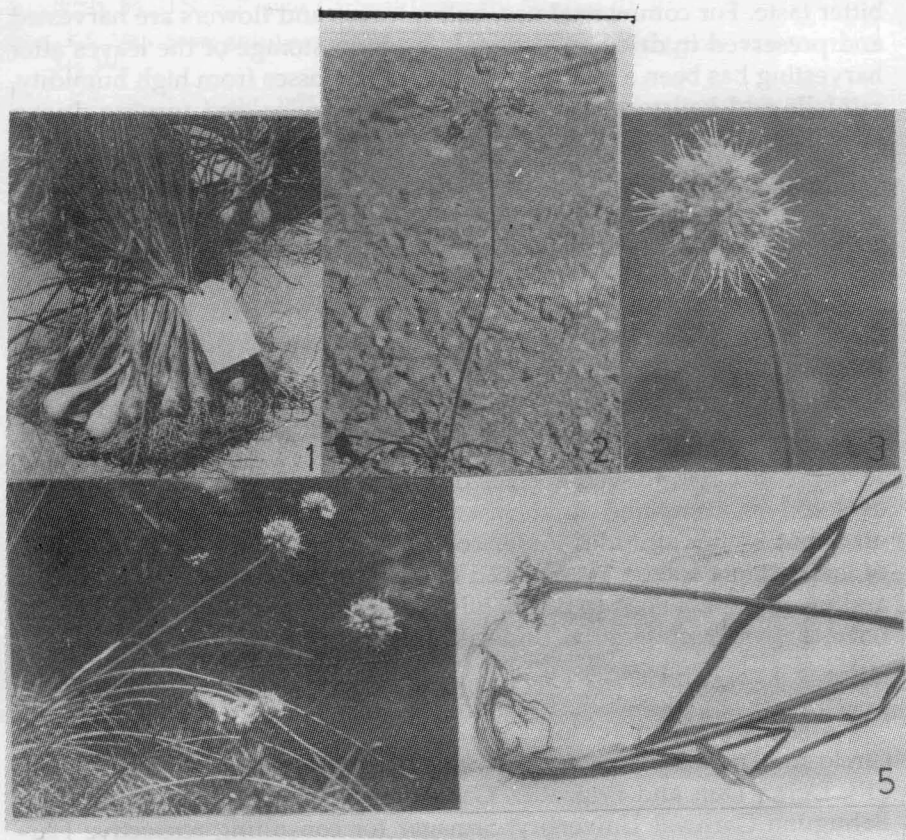


Fig. 1 *Allium ascalonicum* L.

Fig. 2 *A. chinense* G. Don

Fig. 3 *A. consanguineum* Kunth

Fig. 4 *A. rubellum* M. Bieb.

Fig. 5 *A. tuberosum* Rotl. ex Spreng.

METHOD OF UTILIZATION

In Himalayan zone, the wild species of *Alliums*, most often called *Doona*, *Dunn*, *Dhun*, *Pharan*, are the aromatic green vegetables used in pulverized state, primarily for seasoning or garnishing foods and beverages. These are characterized by pungency, strong odour, sweet and bitter taste. For commercial use, bulbs, leaves and flowers are harvested and preserved in dried condition. Long term storage of the leaves after harvesting has been a problem mainly due to losses from high humidity, rainfalls and hailstorms. In such cases, sun-drying and furnace drying have been successful against spoilage and for prolonging storage life upto 12-14 weeks.

During the natural season of wild *Allium* species in the month of April to November, sprouting, flowering and senescence occur. The plant parts such as leaves, flowers and bulbs are harvested, collected and supplied by the natives from their difficult wild habitat. But in recent years, due to heavy demand of dried leaves of *Allium auriculatum* Kunth, *A. humile* Kunth, *A. rubellum* M. Bieb., these have occupied a significant place in hill agriculture as semi-domesticated crops (Negi, 1986, 1988; Negi and Gaur, 1991; Negi and Pant, 1992).

To conclude the wild species of *Allium* have been relatively under-explored as compared to their commercial potential. These may be grown at higher altitudes under cooler climates. So far the exploitation of these *Allium* species is restricted to the natives. However, such valued and useful plants need to be scientifically evaluated to screen promising ones for wider cultivation under standardized package of practices.

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Short Communication

SEED DORMANCY IN PIGEONPEA GERMPLASM

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Dormancy due to hard seed coat is a characteristic feature of many species in the family Fabaceae (Barton, 1965) to which pigeonpea (*Cajanus cajan*(L) Millsp.) belongs. The hard seed coat acts as a barrier to absorption of water, resulting in failure or delay of germination even under favourable conditions. Apart from reduced emergence in soil when sown for multiplication, hard seedness will result in preferential selection for non-dormant types and consequent genetic drift in populations of heterogenous germplasm accessions.

The world collection of pigeonpea germplasm, consisting of 11, 482 accessions from 54 countries, is conserved at 4°C and 20 per cent relative humidity (RH) as an active collection in ICRISAT genebank at Patancheru, India. Every year, sets of this germplasm are grown in the field for evaluation and seed multiplication. During the course of systematic testing for viability, varying degrees of dormancy associated with the hard seeds in several germplasm accessions was observed. However, there is a little published information on the problem of dormancy in pigeonpea.

To find out the extent of dormancy associated with hard seeds in pigeonpea, germination studies were undertaken in a set of 100 medium-duration germplasm accessions. The seeds used in the study were harvested during March-April, 1990 from a crop sown on 30 June, 1989. Following harvest, the seeds were sun-dried to reduce the moisture content and a random test on the accessions showed that seed moisture content varied between 8.5 and 9.6 per cent (wet weight basis). The percentage of hard seeds was assessed by conducting the standard germination tests. One hundred seeds in two replicates were incubated at 25°C, in plastic germination boxes (12 x 10 x 5 cm) on agar (1%) substratum and the first counts for germination were made on the 10th day of testing. The ungerminated, healthy seeds were scarified by a fine cut using blade and incubated for a further period of 5 days. The final

counts on germination were taken on the 15th day of testing. The initial germination among the accessions tested varied from 28-100 per cent, as the percentage of hard seeds was between zero and 71. Three accessions showed over 50 per cent hard seeds, 14 accessions had between 26 and 50 per cent hard seeds and 20 accessions had no hard seeds. The maximum percentage of hard seed (71%) was recorded in two accessions (ICP 619 and ICP 633). Hard seeds in all the accessions germinated after scarification and total germination in the different accessions varied between 94 and 100 per cent (Table 1).

Table 1. Range in percentage of hard seeds, initial germination and final germination after scarification in 100 pigeonpea germplasm accessions

Hard seeds (%)	No. of accessions	Initial germination (%)	Final germination (%)
0-9	65	90-100	94-100
10-19	14	84-89	95-100
20-29	9	69-80	97-100
30-39	5	62-69	98-100
40-49	4	51-58	96-100
50-59	1	44	100
60-69	0	-	-
70-79	2	28	99

A comparison of the seed moisture content (Table 2) with the percentage hard seeds observed in germination tests in five randomly selected accessions revealed an interesting relationship i.e., below a critical moisture level (9.5%), the number of hard seeds increased. Thus, the percentage of hard seeds was highest in accessions which reached lower levels of equilibrium seed moisture contents during sun-drying, compared to other accessions

Table 2. Seed moisture content and percentage of hard seeds in five randomly selected pigeonpea germplasm accessions

Accessions	Seed moisture content (%)±S.E.	Hard seeds (%)
ICP 404	9.6±0.03	0
ICP 57	9.5±0.06	0
ICP 92	9.4±0.02	33
ICP 615	9.2±0.22	56
ICP 633	8.5±0.05	71

Studies on the persistence of dormancy during storage in 13 accessions, showed over 25 per cent hard seeds. The seeds were harvested in March, 1975 and were in storage at 4°C and 20 per cent RH from

June 1975. After 10 days of testing, the germination in these accessions ranged between 66 and 97 per cent and hard seeds varied from 3 to 34 per cent. The degree of dormancy was less than that of the freshly harvested seeds in 12 accessions. This showed that in pigeonpea, dormancy due to hard seed coat was not removed completely even after prolonged storage.

Two broad categories of dormancy related to hard seededness, reversible and irreversible, have been recognised (Ellis *et al.*, 1985). Reversible hard seededness occurs at seed moisture contents around 10-20 per cent, but is gradually lost if the seed is exposed to high relative humidity for a long time. On the other hand, irreversible hard seededness occurs in seeds dried to moisture content of around 5-7 per cent.

In the present studies, the seed moisture content in different accessions was in the intermediate range between the two types (Ellis *et al.*, 1985). Hence, it is not surprising that some hard seeds are retained even after 15 years of storage. For long-term conservation, seeds are dried to moisture content as low as 5 per cent, and the irreversible hard seededness could have serious implications by affecting plant stand during germplasm regeneration. In view of this, the relationship between seed moisture content and aspects of dormancy related to hard seededness need to be studied further.

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Short Communication

**EFFECT OF LOW TEMPERATURE TREATMENT IN
BRASSICA JUNCEA L.**

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In northern India, sudden fall of temperature below freezing point often causes damage to crop yields especially to rapeseed and mustard where the yield losses are reported to be as high as 70 to 90 per cent (Kumar and Kumar, 1989). The damage is attributed to ice formation in the plant tissue (Levitt, 1980). Keeping this in view, the present study was undertaken in *Brassica juncea* L. grown under field condition to investigate effect of low temperature on seed number per silique, an important seed yield contributing trait, by using a movable freezing chamber. The information would be utilized for breeding frost tolerant lines.

The material comprised thirty diverse varieties (strains) of *Brassica juncea* L. (Table 1). These were planted under field conditions in 1 m² plots. Row to row and plant to plant distances were 30 x 10 cm. Untreated plots of the same size were left within each type of plant stand. The freezing treatments were carried out by moving the freezing chamber into the plant stand, putting the detachable side panels into position and connecting the tubes from the refrigeration unit (Ohlsson, 1987). The freezing treatment was given at 50 per cent pod formation stage. The plant stands were exposed initially to 2°C for 30 minutes followed by -2°C for 1.30 hours. Then a more severe freezing shock of -3.5°C was administered for another 30 minutes since the most distinctive change in yield reduction was expected in the interval of 0 to -3°C (Eif and Ohlsson, 1987). The plant stand was then allowed to thaw for 15 minutes before the side panels and tubes were disconnected. Thereafter, panels were partly opened for 15 minutes and the freezing apparatus was moved out of the treated plots.

The number of healthy seeds per silique was counted from lower, middle and upper positions. The observations were based on five siliquae from each position on each of five plants and then averaged.

Table 1. List of varieties/strains tested for frost tolerance

<i>Durgamani</i>	RW 175	RN 156	RN 162	RN 169
<i>Kranti</i>	RN 150	RN 157	RN 163	RN 170
RH 781	RN 151	RN 158	RN 164	RN 171
RH 848	RN 152	RN 159	RN 165	RN 191
RH 7361	RN 154	RN 160	RN 166	RHS 8520
RH 8520	RN 155	RN 161	RN 167	Varuna

Number of healthy seeds were counted. Simultaneously, the data on number of healthy seeds per siliqua on control plants at comparable positions were also recorded. The per cent reduction of healthy seeds in treated plants was calculated over the untreated control plants. The per cent reduction of healthy seeds in treated plants ranged from 11.97 to 55.90 (Table 2). The low per cent reduction of healthy seeds per

Table 2. Varieties/strains of *B. juncea* showing tolerance for low temperature on the basis of per cent losses in seeds per siliqua

Varieties/ strain	Pedigree	Losses in seeds/ siliqua (%)
RN 150	RS 751 X RW 175-1	15.00
RN 154	RS 64 X RW 175	18.82
RN 160	YRT-3 X RW 175-1	12.15
RN 161	Varuna X RW 175-2	16.66
RN 162	T 6342 X RW 175-1	19.03
RN 165	TM 7 X RW 175-8	17.48
RN 167	(UVR-12 X RW 175) X Varuna	20.00
RN 170	(UVR-12 X RW 175) X Varuna-7	11.97
<i>Kranti</i>	Selection from Varuna	19.39

siliqua depicts freezing tolerance while high per cent reduction exhibits freezing susceptibility. Keeping this as basis of screening, the varieties per strains were classified into 3 categories, viz., tolerant (0 to 20% seeds killed), susceptible (20 to 70% seeds killed), and highly susceptible (71 to 100% seeds killed). Table 2 shows 9 varieties/strains displaying tolerance which might be due to the presence of frost tolerant parent RW 175 in all except *Kranti*. The above elite strains therefore could be gainfully utilized for breeding frost tolerant varieties.

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Short Communication

**GARLIC MOSAIC VIRUS DISEASE:
OCCURRENCE AND SCREENING FOR TOLERANCE**

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Exotic and indigenous germplasm of garlic, an important spice crop, is maintained and evaluated at NBPGR for eventual exploitation in developing high yielding and disease free promising varieties. The present note deals with occurrence of garlic mosaic virus (GMV) disease in the germplasm collection and identification of promising tolerant lines to this virus disease through field screening.

A total of 897 germplasm accessions of garlic were grown for evaluation at NBPGR Experimental Farm, Issapur during *rabi* 1989-90. These accessions comprised 10 entries from coordinated trials, 31 exotic accessions mainly from Taiwan and Egypt and 856 indigenous collections. Six to eight week-old plants of many lines started revealing viral disease symptoms on the leaves. These symptoms were found to be mainly of two kinds i.e. either faint to clear mosaic on the leaves (Fig. 1) or longitudinal chlorotic streaks of a few mm width, often extending along the entire leaf length. In a few lines, both these symptoms could be simultaneously observed on different plants. The number of plants revealing such disease symptoms increased with time and eventually at 10-12 week growth stage, the entire field appeared pale and diseased from a distance. The earlier infected plants had reduced growth as compared to those of the same accession infected at a later stage in the growing season in many accessions.

In order to carry out sap transmission study, diseased leaves (with both mosaic and chlorotic streak symptoms) were ground in phosphate buffer (0.1M, pH-7.2) and inoculated on certain indicator hosts, viz; *Chenopodium album*, *C. quinoa*, *Nicotiana tabacum* and *Vinca rosea*. None of these plants showed symptoms on inoculation. Sap inoculation on garlic plants was not done due to non-availability of completely symptom free plants. Randomly collected leaf samples showing mild to severe mosaic and chlorotic streak

symptoms when subjected to electron microscopy (at IARI, New Delhi) by the adopting dip method revealed virus particles as long flexuous rods of about 600 nm size. The samples from leaves with two different types of symptoms (i.e. mosaic and chlorotic streak) revealed virus particles of similar shape and size under electron microscope. Also leaves with both mosaic & streak symptoms gave positive serological reaction with antiserum of Garlic Mosaic Virus (supplied by Dr. Y.S. Ahlawat, IARI, New Delhi) in a microprecipitation test. Based on these results the virus under study was presumed to be garlic mosaic virus.



Fig. 1: Mosaic symptom on garlic leaves infected with garlic mosaic virus.

In India, garlic mosaic virus disease was first reported from Darjeeling hills on the basis of symptoms, transmission studies and physical properties (Ahlawat, 1974). The identification of the virus and prevalence of this disease in India has been recently reported (Ahlawat & Chakraborty, 1990). It has been reported from many other countries also and yield losses of more than 50 per cent have been recorded (Messiaen *et al.*, 1981). There are conflicting reports about the mode of transmission and spread of GMV in the field as it is reported to be transmitted by the aphids, *Myzus persicae* and *Aphis gossypii* (Ahlawat, 1989), *Neotoxoptera formosana* (Abiko *et al.*, 1980) and eriophyid mite, *Aceria tulipae* (Ahmed & Benigno, 1984). In order to screen the available germplasm for resistance, incidence of GMV was recorded in

the field based on symptoms of the disease. The observations were recorded twice (at one month interval) in order to ensure recording of susceptible types having delayed infection during the growth period. None of the 897 garlic accessions were found to be immune or resistant to the disease. However, 9 lines which revealed very mild symptoms were not easily distinguishable from healthy plants. These tolerant lines with near absence of symptoms were: IC-32662, -35325, -49345, -49364, -49373, -49383, G-41, T-84/10 and T-96/13. Mild or faint symptoms were recorded on plants of 239 lines whereas moderate to severe symptoms were noted on plants of 639 lines. These included the otherwise promising accessions of the All India co-ordinated trial namely, EC-158250, G-1, G-50, T86/Sel-1, Sel-2, Sel-10 and Pusa Sel-10. During 1990-91 growing season, heavy incidence of GMV disease was again observed in the germplasm collections in the same field. The 9 lines recorded to show very mild symptoms during 1989-90, were again evaluated for their reaction to GMV. Six of these 9 lines (viz., IC-32662, -35325, -49364, -49473, -49383 and T-84/10) revealed clear symptoms of GMV either in the form of mosaic or streaks or both on different plants. However, plants of 3 lines, viz., IC-49345, G-41 and T-96/13 were again found to be apparently disease-free as observed in the previous year under high natural incidence of disease outbreak in the field. At a later growth stage just before drying up of plants, the younger leaves of few plants of these lines also started revealing mild mosaic symptoms whereas the older leaves still remained symptomless or had very mild symptoms. Nonetheless, the 3 promising tolerant lines, viz., IC-49345, G-41 and T-96/13, all from Maharashtra state, could serve as a good source of GMV tolerant material in the absence of resistant or immune lines in the garlic germplasm collection in India. Further evaluation of these 3 lines at different locations would be useful in assessing their tolerance to different strains of GMV. The tolerant line G-41 is already a released variety of garlic and could be a variety of choice for minimising the damage to the crop from GMV at present.

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Short Communication

**QUALITY CHARACTERISTICS OF SOME BACTERIAL
LEAF BLIGHT RESISTANT RICE GENOTYPES**

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Bacterial leaf blight (BLB) caused by *Xanthomonas campestris* pv. *oryzae* is one of the major diseases of shallow rainfed uplands and medium lands of plateau region of Bihar. Since host resistance is one of the economical and effective way of combating diseases and pests, there is a need to identify suitable donors for BLB resistance for utilization in varietal improvement programmes. Donors with multiple desirable traits are preferred for the simultaneous improvement of a number of traits. Hence, some bacterial leaf blight resistant genotypes were evaluated for grain and cooking quality components.

Twenty eight traditional and two improved cultivars suitable for typical shallow rainfed upland ecosystem were grown during the wet seasons of 1989 and 1990 to study their reaction to bacterial leaf blight. Thirty days old seedlings were transplanted in 1m rows spaced 15 cm between and within a row. There were two rows for each test entry. Taichung Native 1 was planted all-around the experimental plot as susceptible check. The crop was raised at 120:40:20 kg/ha of NPK. One third of N, full doses of P and K were applied as basal and the remaining N was topdressed in two equal halves. The plants at maximum tillering stage were clip-inoculated with the bacterial suspension prepared by soaking infected leaf pieces in water for 20 min. (Kauffman *et al.*, 1972). The genotypes were scored for bacterial leaf blight reaction 14 days after inoculation following the standard evaluation system for rice (IRRI 1988). Quality characteristics were determined using standard method as described in our earlier report (Variar *et al.*, 1990).

Ten genotypes, local *basmati* (HRC 97), *Kalamdani* (HRC 213), *Dudhrais* (HRC 221), *Raria* (HRC 268), *Ramkel* (HRC 272), *Tilasar* (HRC 273), *Cauvery* (HRC 296), *Brown gora k* (HRC 401), *Ch 45* (HRC 442) and *Lalki* (HRC 605) gave resistant reaction with scores of 3.54 or less. Five of

these cultures having consistent reactions in both the years were also evaluated for physico-chemical and cooking quality characteristics. *Kalamdani* (HRC 213) only had long slender grains. There was not much variation in hulling and milling recovery of these genotypes but head rice yields varied substantially. *Lalki* (HRC 605) had the highest head rice recovery. All the five BLB resistant cultures had desirable levels of amylose content (20-25%). *Kalamdani* and *Raria* possess intermediate alkali score and high volume expansion (Table 1) while *Raria* also exhibited maximum water uptake (370 ml). *Lalki*, although could be a good donor for BLB, high head rice yield and kernel elongation, but had the lowest water uptake and medium type of grains and also showed high gelatinization temperature (low alkali score).

Table 1. Quality characteristics of some promising bacterial blight resistant genotypes

Characters	Genotypes				
	Kalamdani	Raria	Ramkel	Tilasar	Lalki
100 grain wt (g)	25.68	30.04	25.04	24.00	24.36
Hulling recovery (%)	76.00	79.00	77.00	75.00	76.60
Milling recovery (%)	70.50	74.20	71.10	70.10	71.70
Head rice yield (%)	65.90	45.30	58.10	37.10	68.00
Milled kernel length (L) (mm)	7.02	5.88	5.68	6.12	5.63
Milled kernel breadth (B) (mm)	1.98	2.80	2.34	2.44	2.45
L:B	3.54	2.10	2.43	2.51	2.30
Alkali value	3.50	3.50	2.80	2.70	3.00
Amylose content (%)	22.12	20.91	21.48	20.33	22.12
Water uptake (ml)	340.00	370.00	330.00	290.00	185.00
Volume expansion	4.30	4.30	3.70	3.70	4.00
Kernel elongation	1.77	1.77	1.79	1.60	1.81

The results suggest that all the five genotypes have atleast one or two good quality traits. However, *Kalamdani*, *Raria* and *Lalki* possess larger number of desirable cooking and market quality traits and should be utilized in the breeding programmes to enhance the possibility of isolating more recombinants with BLB resistance, good cooking and milling quality traits in segregation generations.

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