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The Landraces of Maize (*Zea mays* L.): Diversity and Utility

BM Prasanna* and Lata Sharma

Division of Genetics, Indian Agricultural Research Institute, New Delhi-110 012

Landraces, the germplasm maintained by the farmers over the decades or centuries, were evolved and selected to thrive under particular environmental conditions and to meet local food preferences. Although maize originated in Mexico, landraces of this crop of worldwide importance are widely spread across the continents. India too forms a rich hub of diversity for maize landraces, particularly in the North-Eastern Himalayan (NEH) region. These landraces provide immense range of useful genes that could be efficiently utilized for allele mining and population improvement. Maize landraces of Americas and Europe have been subjected to intensive molecular analyses in the last 10-15 years, leading to significant insights regarding diversity, population genetic structure and global migration routes. Comprehensive genetic and agronomic knowledge of the landraces is critical for effective management as well as utilization in breeding programmes. We review here the tremendous diversity of maize landraces worldwide and in India, and the prospects for tapping this vast genetic potential.

Key words: Maize, Germplasm, Landraces, Genetic diversity, Breeding

The diversity and the utility of maize have been a subject of appreciation since centuries. Maize stands out as one of the most important cereal crops in the world, with enormous role in food and nutritional security. Maize belongs to the tribe Maydeae of the grass family Poaceae. It is the only cultivated species of major economic importance in the entire Maydeae tribe and surpasses all other cereals in its ability to adapt to varied agroecological niches.

Maize diversified first in the highlands of Mexico soon after domestication. Matsuoka *et al.* (2002) showed that the domestication of maize is based on a unique event, and that maize accessions from the highlands of Oaxaca in Mexico are genetically the closest to the wild ancestor of maize (*Zea mays* ssp. *parviglumis*). Maize then spread in all the important agroecologies of tropical, subtropical, and temperate regions. This was possible due to the inherent genetic plasticity of the species, attributed mainly to hybridization of distinctly different races. This, in turn, led to release of significant genetic variability on which both natural and artificial selection operated. The credit must also go to the native Americans whose tireless and effective selection efforts led to the development and maintenance of diverse races of maize that could survive in a wide range of environments to sustain their civilizations. Mutations, migration and genetic drift also played their role in the evolution of racial diversity in maize. This vast diversity provided the foundation for the present-day maize, permitting cultivation from 58°N latitude to 55°S for food, feed, and fodder.

Landraces are an important component of plant genetic resources. Commonly called the 'local varieties' or the 'farmer's varieties', landraces form a genetically diverse, heterogeneous population, that are typically selected by farmers for their adaptation to specific local environment and are understood to differ in agronomic and nutritional characteristics, including plant height, prolificacy, biotic and abiotic stress resistance, maturity, nutritive value, etc. They have evolved under subsistence agriculture and are still cultivated by farmers in regions of crop domestication and diversity. Existence of a vast array of landraces in maize has given a major opening to dealing with the problem of the dwindling resources of alleles. The landraces could serve as an excellent raw material for the development of modern varieties and for crop improvement.

Definition of a 'Landrace'

The unparalleled genetic richness of maize is evident from the existence of well-described landraces from diverse countries. Although Sturtevant (1899) classified maize into six kernel types (flint, dent, flour, pop, pod, and sweet), it was Anderson and Cutler (1942) who first stressed the need for a more natural classification of variability known to exist among maize. They defined race as "a group of related individuals with enough characteristics in common to permit their recognition as a group", and in genetic terms, a race "is a group of individuals with a significant number of genes in common, major races having a smaller number in common than do subraces."

* Corresponding author's E-mail: bmprasanna@gmail.com

of the kernel – Olotillo Amarillo and Olotillo Blanco, with yellow and white kernels, respectively.

Palomero Toluqueño, is well adapted to high elevations, low temperature, and was found to have resistance to the maize weevil, *Sitophilus zeamais* (Arnason *et al.*, 1994). Nal-tel is a widely distributed race in Chiapas and is particularly characterized by a short growing cycle, which makes it desirable to subsistence farmers (Ortega-Pacza, 1973).

The Hopi tribe is a native of the Southwest [states of Arizona, New Mexico, Southern Colorado (USA), and the northern part of Mexico]. They have established a reputation as superior dryland farmers. The Hopi maize landrace is native to Northeastern Arizona. This landrace survives in regions where the better known varieties fail for lack of sufficient water. Like Hopi, its neighbours, Navajos and Zunis are also drought tolerant. Factors responsible for this drought tolerance trait are their ability to force the growing shoot of seedling to the surface of the soil (because of an elongated mesocotyl), when planted deep. Hopis/Navajos/Zunis, all three are often planted at unusual depths of 6, 12, or even 18 inches. At such depths, less specialized varieties die before reaching the surface. Also, each seed produces only a single root. Thus, by concentrating the energy of the seedling into a single root, the latter is forced to greater depths into the soil that is more moist.

Maize Diversity in Asia and India

Distinct types of maize can also be found in Asia, for example, among the hill areas of Mindanao in southern Philippines. Notable among these are some small-eared, early-maturing flint or popcorn types that either have the capacity to grow and mature quickly before being devastated by downy mildew or carry genetic resistance to downy mildew. The most widely used and productive maize of Asia are mainly derived from Caribbean-type flints introduced in relatively recent times. An outstanding population is Suwan-1, derived by breeders in Thailand from composites of mostly flint and semi-flint varieties from the Caribbean islands, Mexico and central America, South America, USA the Philippines, and India (Sriwatanapongse *et al.*, 1993).

The racial diversity of maize in India is small when compared to the Americas but the selection for genetic uniformity and local adaptation indicate a potential for unique germplasm for the maize geneticists and breeders. Extensive variability in plant, ear, and tassel characteristics

is observed in Northeastern and Northwestern highlands of India and relatively less varietal diversity is available in the plains. The social and cultural values of the tribes inhabiting the North-eastern Himalayan (NEH) region played an important role in the conservation of maize landraces, offering significant diversity with respect to plant type, ear characters, quality, biotic and abiotic stress resistance etc. (Figures 1 and 2).

Particularly impressed by the diversity of maize in the North-eastern Himalayan (NEH) region, Anderson (1945) considered maize to have an ancient Asiatic origin, and an early trans-Pacific migration to South America. Subsequent studies by a number of workers, including Stonor and Anderson (1949) and Suto and Yoshida (1956), showed that landraces with primitive characteristics (popcorn characters and high prolificacy) do exist in the eastern Himalayan region (Sikkim in India and Bhutan). Dhawan (1964) christened such landraces as "Sikkim Primitives", whose New World progenitors seem to have disappeared. Based on ear and kernel characters as well as geographical distribution, Bhag Singh (1977) proposed 15 distinct races and three subraces, which were assigned to three lineages, Palomero Toluqueno, Confite Marocho, and Kculli.

Describing and rechristening a popcorn variety of Sikkim as 'Sikkim Primitive' (SP1 and SP2), Dhawan (1964) is credited for arousing great interest in Himalayan maize among the concerned scientists of the world. Although Dhawan (1964) studied only two collections of primitive maize from Sikkim, landraces having characteristics of SP are distributed throughout the NEH region, including Bhutan and Nepal. Sachan and Sarkar (1986) identified 13 different strains of primitive maize from NEH region and designated them as SP strains, although these came from Nagaland, Meghalaya, Tripura and Sikkim.

The most important physiological attributes of SP maize are a complete lack of apical dominance; prolificacy (5-9 ears) with uniformity in ear size; erect leaves for developing maize varieties for high population density; top bearing habit and drooping tassel to ensure effective fertilization (Sachan and Sarkar, 1982). It stays green after maturity; thus it is also good for fodder purposes. It is resistant to stalk rot and has tremendous stem strength, which prevents lodging.

Various collections of 'Sikkim Primitive' types seem to be derivatives of a single widespread popcorn variety grown and selected by different ethnic groups in remote



Fig. 1: (A) Ears of maize landraces hung in a traditional manner in a farmer's house in North Sikkim; (B) Diversity for ear characters displayed by the maize landraces grown by a farmer in the North-eastern Himalayan State of Sikkim in India



Fig. 2: (A) Multi-eared (prolific) maize landrace in Sikkim; (B) Diversity in the maize collections from the Mizoram State in North-eastern India (Photo Courtesy: Dr. DK Hore, NBPGR, Umiam, Meghalaya)

and isolated pockets of the North-eastern Himalayas. Tillering habit was not observed in any of the collections. The increase in the number of ears is associated with the decrease in the number of internodes between the topmost ear and peduncle. It is interesting to note that in 'Sikkim Primitives' many of the ears bearing male inflorescences at the tip are all self fertilized. Such ears are completely covered with long husks, and thus silk does not come out of the husk. Apparently there is no indication of inbreeding depression in these populations.

Sikkim Primitive (locally called as 'Murli') is totally distinct and used only as offerings in ceremonial use among the Buddhistic peoples of the region. This little grown popcorn of Sikkim and adjoining areas occurs at mid-elevation, 2000-2700 m, in moist tropical cloud forest region, and has been claimed to be a primitive sort of ancestral maize. Is this a derivative of a Caribbean

Flint/New England Flint from the plains below? This hypothesis needs to be verified through empirical studies.

Another area worthy of further studies is the Eastern Region of the tribal areas in the states of Arunachal Pradesh, Nagaland, Assam, Manipur, and Tripura. Much of the maize, which is not typically Indian in the region is extremely interesting. Were these maize types introduced by missionaries or were they introduced through the 'silk route'? This needs further analysis. We have a rich haul of maize germplasm from Sikkim, Nagaland, Meghalaya, Tripura, Mizoram, Manipur and Northwestern Bengal. The germplasm can be broadly classified into waxy, sugary, floury, flint, dent and popcorn types.

There are several other landraces of maize with special features, which belong to the regions spanning rest of India, other than NEH region. These could be efficiently used in maize improvement programs for their

respective specialties or importance. Some of them are 'Sathi local', from Punjab, which is a very early maturing (65 – 75 days), heat and drought tolerant landrace and has excellent yield characters and adaptability; 'Basi local' (Rajasthan) has a drought tolerance trait; 'Dausa local' (Rajasthan) has excellent yield characters and adaptability; 'Jaunpur local' (Uttar Pradesh), is resistant to stalk rot and other diseases and is also tolerant to excess water and drought; 'Tulbulia local', from Bihar and Teenpakhia local from Uttar Pradesh, are extra early maturing.

Another area where older landraces are grown is in the foothills of South India, around 1000 to 1600 m in elevation, seasonally dry with a tropical forest vegetation cover. These appear to be modified New England Flints which are very rapid in their maturity and among tribal people in Andhra Pradesh and Orissa are called "hungry children food" because the crop is ready and eaten green (like a sweet corn) before the slower to mature rice crop is ready for harvest. This maize landrace most probably possesses germplasm for disease resistance because all the crops grown in the region show signs of fungal infections.

There is no adequate information about the landraces and no documentation of this rich diversity that could serve as a comprehensive database. It is hence important to attain an extensive genetic and agronomic knowledge of these landraces. This has been recently initiated under the ICAR National Fellow project on "Molecular characterization of Indian maize landraces and allele mining for agronomically important traits".

Global Migration Routes of Maize

It is believed that maize spread from Americas through Southern Europe and into Africa, South Asia and Northwest Himalayas in the 16th century. Since maize is a naturally open-pollinated crop, the varieties that were moved from place to place carried considerable genetic diversity, allowing farmer selection, that led to the development of a vast array of races.

Migration routes of the maize germplasm, as deduced from cytological studies, are of particular interest to anthropologists and students of maize evolution. Researchers identified a number of such routes (Kato, 1984; McClintock, 1978; McClintock *et al.*, 1981). One, described by McClintock (1978), extends along the Pacific Coast of Mexico from the Guatemalan border to the state of Sonora. Another route, a relatively recent one according to McClintock (1978), extends from the Mexican Bajio

into Chihuahua. A third most interesting migration route is that extending along the east coast of Mexico from Veracruz into Tamaulipas. This route includes the highly productive race Tuxpeno, which has contributed significantly to maize improvement in the lowland tropics.

After the discovery of America by Christopher Columbus in 1492, maize moved quickly to Europe, Africa, and Asia, possibly within a span of 100 years. In Italy and Spain, early counterparts of many South American races are evident even today. From Spain, it spread northwards and north-eastwards to the short-growing-season areas of Europe, where selection for early maturity has produced some of the earliest commercial varieties of maize now available. In Europe, until the last part of the 19th century, the flints were the most prevalent type. Later, however, germplasm from highlands of Mexico, early types from Canada and northern USA, and then, some time between 1880 and 1930, the US dents were introduced. Trifunovic (1978) recognized only four racial groups in Europe, including Corn Belt Dent-like forms, South-eastern European Flints, Northern European and Alpine Flint types and the South European or Mediterranean type.

According to a study by Paterniani (2000), the Brazilian maize landraces were derived from crossing introductions from United States (at different times in the past) and maize types cultivated for a prolonged period of time by indigenous tribes and European colonizers after the discovery of the American Continent. In the middle of the 18th century, yellow dent germplasm was introduced to Brazil from the United States, and the white dent germplasm was recently introduced with the Hickory King variety. Doebley *et al.* (1988) reported that yellow dent, white dent, and Hickory King were races derived from Southern United States dent corn types.

Based on molecular analysis of European and American maize populations using SSR markers, researchers from INRA, France, concluded that maize grown in southern Spain comes mostly from the Caribbean, whereas northern European maize originates in the northeastern USA (Northern Flint). It might have been expected that most European maize would be similar to Spanish maize, having been brought back by Columbus and subsequently spread, but maize with Northern Flint characteristics was commonly observed in Germany in the 1540s, suggesting that maize was independently introduced into northern and southern Europe.

Much of the maize now found in Africa is derived from later introductions from the southern US, Mexico, and parts of eastern South America, although it was introduced into Africa soon after discovery. Africa has always preferred white maize; until recently, the varieties grown there were almost exclusively white. In contrast to the intensive studies on maize migration routes in Americas and Europe, there is little information on this aspect with respect to Africa and Asia. This gap is expected to be filled through an ongoing Generation Challenge Program (GCP) collaborative project titled "Characterization of genetic diversity of maize populations: Documenting global maize migration from the centre of origin", involving CIMMYT (Mexico), INRA (France), IITA (Nigeria) and institutions from NARS (India, China, Indonesia, Philippines, Thailand, Vietnam and Kenya).

Antiquity of Maize in India – A Puzzle Ripe for Solution

Post-Columbian introduction of maize into India by the Portuguese in the 16th century or later has been accepted by most of the maize workers. However, the peculiar features of maize being grown in remote North-eastern Himalayan (NEH) tracts adjoining Burma and Tibet have stimulated an interesting discussion among maize workers on the possible pre-Columbian introduction of maize in these hilly tracts of the Himalayas.

Jeffreys (1965) suggested that maize had been introduced by the Arabs and not by the Portuguese, in the pre-Columbian era. Kuleshov (1928) reported that varieties similar to those described from the Naga tribes are widespread in Central Asia from Persia and Turkestan to Tibet and Siberia. The deep involvement of maize in the customs, tradition and economy of tribal people in the centre NEH also led to the support for the hypothesis on the prehistoric introduction of maize in these areas (Thapa, 1966). Johannessen and Parker (1989) argued that stone carvings of maize ears exist in at least three pre-Columbian Hoysala stone block temples near Mysore, Karnataka state, India. Vocal critics of Johannessen and Parker argued that what is depicted in these sculptures is in fact not maize, but rather something else - variously *muktaphala* (lit. "pearl-fruit", an imaginary fruit made of pearls), some exotic tropical fruit, etc. (Veena and Sigamani, 1991; Payak and Sachan, 1993). Kumar and Sachan (1993) attempted to provide genetic evidence for the antiquity of maize in India, thus independently corroborating Johannessen and Parker hypothesis of pre-Columbian introduction of maize into India.

Kumar and Sachan (1993) proposed two sets of maize introductions in NEH (a) in pre-historic times through a sea/land route much before the discovery of America by Columbus in 1492, and (b) in the post-Columbian era by Christian missionaries, material which essentially resembles Caribbean germplasm. Empirical studies are required to validate the hypotheses related to antiquity of maize in India.

Cytological Analyses of Maize Landraces

A comprehensive classification of the indigenous landraces of Mexico based on morphological characteristics, internal cytological features and physiological characteristics such as earliness, yield and resistance to diseases, was carried out by Wellhausen *et al.* (1952).

Chromosomal knobs were used to elucidate differences among maize locals of Kashmir valley (Jotshi and Patel, 1983). Fifteen local maize varieties from three districts (Anantnag, Pulwama and Baramulla) of Kashmir valley were collected for the study. Out of these 15 varieties, four were locally known as Tripachi, four as Badeh, two as Vozij, two as Niver, one as Mishri, one as Kani, and one as Ferozpur. Knob number within the varieties of a group showed a lot of variation in the Tripachi group and within the Badeh varieties. Niver varieties did not show any difference between each other, but in Vozij varieties, significant differences were observed.

Cytological characterization of eight Sikkim Primitive (SP) maize strains collected from different parts of the NEH region was carried out by Kumar and Sachan (1992). These included three strains from Meghalaya (M-1, M-15, M-25), two from Tripura (T-2, T-26), two from Sikkim (S-27, S-44) and one from eastern Nepal (SP Nepal). Twenty-six knob forming positions have been identified altogether in different collections of NEH maize. The presence of some new and unusual knob positions in NEH maize, hitherto unknown in American maize races, had been identified in this study. The presence of these new knob positions in different regions suggested their adaptive value and indicated the uniqueness of NEH maize. On the basis of chromosome knob number, these SP strains were grouped into two categories: low knob number group (4 knobs) and high knob number group (6-11). When these two SP groups were compared with those of American primitive races, the low knob number SP group was shown to have its linkage from *Confite Morocho* of Peru and/or *Palomero Toluqueno* of Mexico. In contrast, the high knob number group of SP strains possesses close similarity to the *Nal-Tel-Chapalote*

complex. Based on information obtained from studies on botanical, C- and Q-banding, pachytene analysis, ethnobotany, and interpretation of the archaeological findings led to a hypothesis (Sachan *et al.*, 1984) that the pre-historic wild corn, which evolved in the extreme desert environment in the Tehuacan valley of Mexico, is well preserved in the form of Sikkim Primitive.

Biochemical Characterization of Maize Landraces

Evidence of a great dissimilarity between Northern Flint and Southern Dent landraces of North America was demonstrated through isozyme diversity analysis by Doebley *et al.* (1988). Twenty-three isozyme loci representing 13 enzyme systems were used for the study. The isozyme data supported the view that Midwestern Dents arose from the hybridization of Northern Flint from New England and Southern Dent, and the Midwestern Dents contain a greater share of Southern Dent germplasm as compared to the Northern Flints.

The genetic variability among 15 populations from four indigenous races of maize - Caingang, Entrelaçado, Lenha and Moroti - that occurred historically in Brazil, and five indigenous cultivars, were analyzed by Gimenes and Lopes (2000) using five isozyme systems encoded by 14 loci. The study showed no correlation between the accessions name and the genetic relationships. Also, the genetic similarity among populations collected in different geographic regions, was sometimes higher than that among populations from the same race, collected at sites very close to each other, indicating that there is little correlation between the geographic and genetic distances among populations.

Bhat *et al.* (1998) attempted to elucidate the interrelationships between maize landraces of NEH and Mexico using the esterase, peroxidase, and acid phosphatase profiles. The study showed that maize landraces grown by the tribal people of North-eastern India are of significant antiquity as they bear a close resemblance to the prehistoric wild corn. The analysis indicated a wider diversity among the maize accessions collected from Tripura, Uttar Pradesh, Nagaland, Sikkim and Meghalaya (the four forming one sub-cluster), and Nal-tel, a Mexican landrace, was closely related to these landraces.

Molecular Analyses of Maize Landraces

Genetic variation among 15 accessions of Native American maize from the Great Plains was investigated using RAPD (Moeller and Schaal, 1999). The study revealed very high levels of polymorphism among accessions, indicating

that many maize accessions were introduced through trade into those regions or migrated with indigenous tribes who had begun maize agriculture in other localities.

Using the bulk RFLP analysis, Gauthier *et al.* (2002) undertook molecular characterization of 488 European maize populations. Populations from Eastern Europe (Poland, Austria, Germany, etc.) showed the lowest genetic diversity, a lower number of unique alleles and a higher percentage of fixed loci than populations from Southern Europe. Genetic diversity was higher in the Southern regions where the first maize populations are thought to have been introduced. A correlation between allelic frequencies at some loci and latitude and/or longitude was observed. Such tendencies may reflect the direction of gene flow between different races of maize; for instance, North American (Northern Flint) and Caribbean populations were introduced, respectively, to northern and southern Europe, in the past. According to Brandolini (1970), maize was not introduced into Greece directly from Americas, but probably derived from the Balkan populations. This historical perspective of introduction may explain the relatively low diversity of Greek populations. This observation is in contrast to the allelic richness and high number of unique alleles in races from Portugal, Spain and Italy, where maize is known to have introduced from America during the 16th century (Revilla *et al.*, 1998).

A comparative characterization of farmer populations of the flint maize Italian landrace "Nostrano di Storo" was carried out by Barcaccia *et al.* (2003) using different types of PCR-based (SSR and ISSR) markers. An inbred line and three synthetics selected from as many landraces were used as reference standards. Although a high variability can be found among plants, most of the genotypes belong to the same landrace locally called 'Nostrano di Storo'. This result was also confirmed by a further molecular investigation using AFLP and RAPD markers to fingerprint pooled DNA samples from all farmer populations. Although gene flow from commercial hybrids might have occurred, the large number of polymorphisms and the presence of both unique alleles and alleles unshared are the main factors underlying the value of this flint maize landrace as a source of genetic variation.

The genetic relationships among 81 maize accessions (consisting 79 landraces and two improved varieties), maintained by farmers in southern Brazil were investigated using Random Amplified Polymorphic DNA (RAPD),

with 32 polymorphic primers (Carvalho *et al.*, 2004). The highest genetic similarity was observed between the Branco Lastek Dinart and Cunha Branco landraces. These accessions have been cultivated in distinct regions by unrelated small farmers and are known by different names. In contrast, two other accessions, Astecão Branco and Asteca Branco that have been treated by similar names were less related by RAPD. The Asteca landrace, which showed the lowest similarity to the other accessions, has an uncertain origin and seems to have been derived from a sample collected a few years ago by small landholder farmer. This study also revealed that maize management adopted by small-scale farmers contributed to the maintenance of genetic variability.

Study of the populations of maize landraces cultivated in six villages of the Oaxaca region of Mexico (Pressoir and Berthaud, 2004 a,b) revealed that the morphological and agronomic characters in the field, such as ear size, kernel colour, or flowering period, vary depending on the farmer. At genome scale, microsatellite markers revealed strong homogeneity between the maize populations within the same village and, more surprisingly, between distant villages. This investigation brought the first genetic proof that cultivation practices, conducted on a small scale (village and region), are a key element in the evolution of maize and its diversity. In-situ conservation of so-called "farm" varieties of crop plants, following the example of maize, could therefore be perceived in terms not of isolation, but of dynamic means of gene flow between different populations of the same region in which the farmers play a predominant role.

The first detailed molecular characterization and a population genetic analysis of selected Indian maize landraces was initiated by Prasanna *et al.* (2005). Seventeen selected landraces from diverse agro-ecologies, including 10 accessions from the NEH region and 7 from other agro-ecologies, were analyzed using 27 polymorphic SSR markers. Population genetic analysis, including Wright's F statistics of the SSR data revealed greater genetic divergence among the NEH landraces in comparison with the landraces from other regions.

Utility of Maize Landraces in Crop Improvement

There are various reasons attributed to a farmer's selection, maintenance and retention of landraces and these include storage, cooking, nutritional, and processing qualities; historical and cultural factors such as dietary diversity and use in traditional foods or religious ceremonies. Another cause may be for agronomic reasons: some folk

varieties are considered more suited to traditional intercropping patterns, have longer or shorter growing cycles, or are more resistant to local biotic and abiotic stresses (Dennis, 1987; Bellon, 1990; Brush, 1991; Brush *et al.*, 1992; Zimmerer, 1991; Ferguson and Mkandawire, 1993; Longley and Richards, 1993; Soleri and Cleveland, 1993; Soleri *et al.*, 1994). Yield stability is also an important reason for retaining these folk varieties. For example, the Hopi tribe in South America still retains the blue maize landraces because these are adapted to drought, have a short growing season and meet their cultural requirements.

Agronomic performance

Two objectives in evaluating landraces are: (a) to identify the best local populations that could be used broadly, and, (b) to identify populations that will be starting material for crop improvement. Suwan-1, the popular OPV from Thailand, has been used to develop a commercial cultivar, a composite "Parbhat" was developed by the Punjab Agricultural University, Ludhiana. This composite shows multiple disease resistance, high yield and stability in performance (Dhillon and Prasanna, 2001; Dhillon *et al.*, 2002).

Broad based pools formed using promising landraces for specific traits are excellent material for population improvement programmes. Population Improvement through recurrent selection aims at increasing the frequency of favourable genes in a population progressively over successive generations, while maintaining reasonable levels of genetic variability. For example, at Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS), Almora, Uttaranchal, landraces from Jammu & Kashmir as well as the Uttaranchal states in India were effectively utilized for developing a broad-based genepool. Using this germplasm, several inbred lines and hybrids that are well adapted to hill areas were derived. The popular hybrids include Him-129 (yellow, flint, 85-90 days maturity, highly tolerant to leaf blight); Him-128 and several 'Vivek' hybrids.

Prasanna *et al.* (2005) evaluated 27 selected landraces from diverse agro-ecologies in India, including 10 accessions from the NEH region, along with the inter-population experimental crosses, were evaluated for their agronomic performance at two locations in India (Hyderabad and Delhi) during 2003 and 2004. Significant genotype x environment interactions were observed with respect to the agronomic performance of the landraces as well as the experimental crosses. Nevertheless, Sathi

local, Jaunpur local, Dausa local, Jhabua local and S51 among the landraces revealed excellent yield potential and adaptability. Evaluation of yield performance of experimental crosses, derived using the seven locals from the non-NEH region, led to the identification of Sathi local and Dausa local as the best general combiners at Hyderabad and Delhi, respectively. At Hyderabad, Sathi local x Jhabua local, Sathi local x Dausa local, and Jhabua local x Arabhavi local showed top ranks for several yield components, while at Delhi, Dausa local x Jaunpur local, Dausa local x Jhabua local, and Bhowali local x Arabhavi local were found to be highly promising. Some entries even outperformed the popular hybrid, Parkash, indicating the tremendous genetic potential of these landraces in improving maize productivity, particularly through population improvement. A more extensive agronomic evaluation of nearly 300 Indian maize landraces is in progress.

Biotic stress resistance

A number of studies in maize indicated the potential of the landraces in improving biotic stress tolerance. For example, 28 landraces of maize from Mexico were assessed for susceptibility to the maize weevil, *Sitophilus zeamais* in standardized resistance tests (Arnason *et al.*, 1994). Susceptibility parameters such as grain weight loss, number of insect progeny produced, and the Dobie index of susceptibility, were found to vary significantly by genotype, with exceptional resistance found in accessions representing the Naltel, Chapalote and Palomero landraces.

A set of the indigenous races of Mexico, differing in altitudinal adaptations, were assessed for resistance to the European corn borer, *Ostrinia nubilalis*, by Reid *et al.* (1990). Correlations of altitudinal origin with resistance were found for the Mexican races. There was an increased susceptibility to borer tunneling and stalk rot resistance in higher altitudes. Also, since tropical plants are more exposed to various species of insects than temperate plants, this could have led to the selection of maize with greater resistance to fungi in these regions than in temperate zone plants.

Abiotic stress tolerance

Michoacan 21, a collection from Mexico, which is the source of *latente* gene, has shown an unusually high recovery after a strong drought stress (Munoz, 1975). It was resistant to permanent seedling wilting and tissue desiccation, with high transpiration under irrigation and low transpiration under stress. The Hopi farmers in

Arizona, USA, plant primarily landraces of field crops mainly because this germplasm exhibits considerable tolerance to drought stress. The ability of Hopi blue maize to emerge from seeds planted as deep as 25 cm is a specific adaptation to the arid climate and soils of the Hopi homelands (Soleri and Cleveland, 1993).

Studies carried out at Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS), Almora, Uttaranchal, with 15 'Sikkim Primitives' collected from the NEH region, during *kharif* 1986, revealed that these landraces could serve as a potential source for drought tolerance in maize breeding programmes (Mani *et al.*, 1987).

Rodriguez *et al.* (1998) analyzed the physiological aspects of Tuxpeño maize with relevance to its drought tolerant characteristics. Physiological factors such as stomatal conductance, leaf photosynthetic rate and detectable abscisic acid levels were analyzed, besides parameters change in Tuxpeño landrace with successive generations.

Quality traits

The long-term selection experiment for kernel oil and protein content in maize was initiated at the University of Illinois, Illinois, in 1986 by C.G. Hopkins (Hopkins, 1899) and culminated in 2002 (Dudley and Lambert, 2004). This '100 generations of corn' experiment was started using the 'Burr's white' landrace of the Burr's county, Illinois, USA. The extraordinary continuity of this experiment in itself is remarkable. The original objective was to determine whether the chemical composition of the maize kernel could be changed by selection. As the experiment continued, the objective was modified to determine the limits of selection for kernel oil and protein and to select strains - Illinois High Oil (IHO), Illinois Low Oil (ILO), Illinois High Protein (IHP) and Illinois Low Protein (ILP). These strains were further used to detect QTLs for protein, oil, and fatty acid composition (Willmot *et al.*, 2006).

Fourteen accessions of three types of maize (convar. *mays*, convar. *dentiformis*, convar. *microsperma*) landraces from the germplasm collection at the Institute for Agrobotany, Hungary, differing with respect to endosperm color (yellow to orange), were analyzed for carotenoids (polyoxycarotenoids, lutein, zeaxanthin, β -zeacarotene, zeinoxanthin, cryptoxanthin) and total colour content, using high performance liquid chromatography (HPLC) [Daoud *et al.*, 2003]. The study provides evidence for carotenoids differences among the maize landraces, and

identified promising landraces with highest concentration of lutein, zeaxanthin and cryptoxanthin (precursor of vitamin A). Such accessions are of special interest from nutritional and biological points of view.

Managing the Vast Maize Genepool

Often, the size of germplasm collections limits their accessibility and greatly discourages effective management, evaluation and utilization of available germplasm. To improve this situation, the concept of 'core collection' was suggested by Frankel and Brown (1984). They defined a core collection as a representative sample of a collection where the diversity is retained as much as possible with minimum of redundancy. The accessions not included in the core serve as the reserve collection, composing the collection's back-up. Core subsets of landraces feature useful traits such as high yield, grain quality, disease resistance etc.

Taba *et al.* (1998) developed a core subset of Caribbean maize accessions from the CIMMYT maize germplasm bank. Most accessions were from West Indies and others were from Central and South America. They evaluated and used morphological traits like, plant height, ear length, senescence, ear diameter, days to silk, days to anthesis and number of kernel rows, to cluster accessions into homogeneous groups.

Matosetti and Abadie (2001) compared three classification strategies in establishing a core collection of Uruguayan maize landraces and concluded that a combination of kernel type and geographic origin was the best classification rule since it took into account two points which were closely related to the distribution of diversity: genotypic composition and geographic origin.

At the Institute of Crop Germplasm Resources, Beijing, China, Li *et al.* (2004) have attempted to produce a core collection out of 13,521 maize landraces preserved in China National Genebank (CNG). The landraces were divided into subgroups in terms of ear type, kernel type, kernel colour, cob colour, plant height, ear height, number of leaves, days from seedling emergence to maturity, ear length, ear width, number of rows, and 1000-kernel weight.

Creating broad-based populations could be another alternative to managing huge collections of accessions. Broad-based population refers to a heterogeneous group of germplasm accessions. It facilitates the management and use of broad diversity of landraces and also broadens the genetic base of a crop. It involves bringing together resources with as many alleles as possible, irrespective

of the target trait. For example, it could combine alleles for various traits like disease resistance, drought tolerance, protein quality etc. Landraces could form the starting material for developing a broad-based population.

Concluding Remarks

Maize landraces have immense genetic diversity. Yet, it is relevant to note that genetic resources used in maize breeding programmes around the world represent less than 10% of all landraces (Dowswell *et al.*, 1996), indicating that much of the genetic diversity remains to be efficiently and effectively explored and exploited. Concerted efforts are required to utilize landraces and wild relatives in generating breeding populations, so as to derive elite germplasm with enhanced productivity and ability to adapt to a range of production environments.

This rich diversity of maize in many countries, including India, appears to be under threat due to various reasons, including the changing nature of agricultural production, and due to widespread adoption of modern varieties.

It is important to develop maize germplasm conservation mechanisms both *ex situ* and *in situ*, by strengthening the role of rural communities in the conservation of biodiversity. It is equally important to study the dynamic conservation of landraces in farmers' fields as well as the relatively more static conservation of landraces in gene banks.

In future, this genetic diversity could enable development of maize varieties that would resist insects and diseases and tolerate drought, saline and infertile soils, and endure other stresses. Landraces possessing these traits are essential for helping people in the developing world to feed their families and improve their economic well-being. Hence, it is now time to take measures to conserve, characterize and utilize these valuable genetic resources. Integration of morphological and molecular surveys is advisable for the study of landraces, and building up genetic resources management strategies.

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Distribution, Diversity and Species Relationships of Wild *Vigna* species in *Mungo-Radiata* Complex

IS Bisht^{1*}, KV Bhat¹, M Latha², Z Abraham², N Dikshit³, Shashi Bhalla¹ and TR Loknathan⁴

¹National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi-110 012

²National Bureau of Plant Genetic Resources, Regional Station, Vellanikkara, Thrissur-680 654 (Kerala)

³National Bureau of Plant Genetic Resources, Regional Station, Akola-444 104 (Maharashtra)

⁴Central Institute for Cotton Research, Nagpur-440 010 (Maharashtra)

A total of 107 populations of 5 *Vigna* species in the *mungo-radiata* complex from different phytogeographical regions of India were collected. These species occurred in different associations as components of the herbaceous and grassy undergrowth or are seen twining on bushes in scrub vegetation. *V. mungo* var. *silvestris* was widespread in northern parts of the Western Ghats. Sporadic occurrence of this species was recorded from parts of Rajasthan, Madhya Pradesh and Maharashtra. *V. radiata* var. *sublobata* was widespread in the Western Ghats. Sporadic distribution of this species was recorded from the north-western Himalayas, parts of Rajasthan, Madhya Pradesh, Maharashtra, and southern parts of the Western Ghats. *V. radiata* var. *setulosa* populations were of sporadic occurrence in northern parts of the Western Ghats and north-eastern region of the Eastern Ghats. *V. hainiana* populations were widespread in central plateau region and parts of the Eastern Ghats. Sporadic distribution of this species was also recorded from north-western Himalayas. *V. khandalensis*, was endemic to northern parts of Western Ghats. Diversity of the collected germplasm for various morphological characters was assessed. Data on 45 selected qualitative and quantitative traits were subjected to multivariate analysis for establishing species relationships and assessing the pattern of inter- and intra-specific variation. Except for *V. khandalensis*, all other species, *V. radiata* var. *sublobata*, *V. radiata* var. *setulosa*, *V. mungo* var. *silvestris* and *V. hainiana* showed greater homology in growth habit. The species, however, differed in other plant, flower, pod and seed characteristics. *V. khandalensis* was distinct from all other species in an erect growth habit, large foliaceous stipules and broad leaves. Within species variations were more in *V. mungo* var. *silvestris* populations. The cultigen types of *V. mungo* and *V. radiata* showed greater homology to the conspecific wild species in morphological characteristics, the former were however more robust in growth, with large vegetative parts, erect growth and three to fivefold increase in seed size and seed weight. Wild species have a great potential as sources of disease resistance and other useful traits. Intensive collection, characterisation and conservation of the species diversity and intraspecific variation, particularly of the conspecific wild relatives with valuable characters, therefore assumes great priority to make extended cultivation economically attractive.

Key words: Asian *Vigna*, *Ceratotropis*, Distribution, Diversity, Species relationships, *Vigna mungo-radiata* complex

The Asian *Vigna* in the subgenus *Ceratotropis*, with 16 to 17 recognised species distributed across Asia (Verdcourt, 1970; Marechal *et al.*, 1978; Tateishi, 1996), constitute an economically important group of cultivated and wild species for which a rich diversity occurs in India. Taxonomically, cultigen and conspecific wild forms are recognised in all cultivated Asiatic pulses, *V. radiata* (L.) Wilczek (mungbean), *V. mungo* (L.) Hepper (urdbean), *V. umbellata* (Thunberg) Ohwi & Ohashi (ricebean) and *V. angularis* (Willdenow) Ohwi & Ohashi (azukibean) except for *V. aconitifolia* (Jacquin) Marechal (mothbean) which has retained a wild type morphology (Marechal *et al.*, 1978; Lukoki *et al.*, 1980). The cultivated species, *V. radiata* and *V. mungo* are of Indian origin as is borne out of their remains in archaeological sites in the sub-continent (Arora *et al.*,

1973; Chandel *et al.*, 1984). The domestication of *V. aconitifolia* is also apparently Indian, whereas that of *V. angularis* and *V. umbellata* is far eastern. Wild *V. angularis* is distributed in Japan and Korea; *V. umbellata* has its origin in Indo-China and Southeast Asia (Marechal *et al.*, 1978; Baudoin and Marechal, 1988).

The Asian *Vigna* are considered to be a morphologically homogenous group which have very specialised and complex floral organs. The work of Maekawa (1955), Baudet (1974) and Tateshi (1996) clearly demonstrated three groups in Asian *Vigna* based on the position of cotyledons on germination and the petiolate or sessile nature of first and second leaves. This was also confirmed by several other workers (Jaaska and Jaaska, 1990; Kaga *et al.*, 1996; Tomooka *et al.*, 1996; Konarev *et al.*, 2000). Lawn (1995), based on

*Corresponding author: E-mail: bishtis@nbpgr.ernet.in

cross compatibility studies, also proposed that Asian *Vigna* consists of three more or less isolated genepools corresponding with groups based on seedling characteristics proposed by Taiteshi (1996). The proposed groups were *radiata-mungo* (mungbean group), *angularis-umbellata* (azukibean group) and *aconitifolia-trilobata* (mothbean group). Tomooka *et al.* (2000) proposed a revised list of taxa in the subgenus *Ceratotropis* and suggested three groups giving them taxonomic rank as Section *Angulares* (azukibean group), *Radiateae* (mungbean group), *Aconitifoliae* (mothbean group), and an undetermined section for *V. khandalensis*. Tomooka *et al.* (2002, 2003) describe relationships among the Asian *Vigna* species under subgenus *Ceratotropis*.

Fourteen species of *Vigna* under the subgenus *Ceratotropis* are reported to occur in India (Arora, 1985). The cultivated species in the *mungo-radiata* complex with conspecific wild forms are *V. mungo* and *V. radiata*. The conspecific wild species in *V. mungo* is *V. mungo* var. *silvestris* Lukoki, Marechal & Otoul. In *V. radiata*, more diversity in wild types occur and two conspecific species *V. radiata* var. *setulosa* (Dalzell) Ohwi and Ohashi and *V. radiata* var. *sublobata* (Roxburgh) Verdcourt are reported. Two more wild species, *V. hainiana* Babu, Gopinathan & Sharma and *V. khandalensis* (Santapau) Raghavan & Wadhwa, endemic to India, have also been accommodated in the *mungo-radiata* complex owing to their similarity to both cultivated *V. mungo* and *V. radiata*. The status of these two species is, however, yet to be resolved.

Other cultivated species with conspecific wild forms include *V. umbellata* (wild type occurring, conspecific with cultigen types – *V. umbellata* var. *gracilis* (Prain) Marechal, Mascherpa & Stainier), *V. aconitifolia* (wild occurring variability conspecific with cultigen types) and the semi-domesticated *V. trilobata* (L.) Verdcourt (wild occurring variability conspecific with cultigen type). No wild types are reported to occur in India for *V. angularis*, *V. dalzelliana* (O. Kuntze) Verdcourt (akin to *V. umbellata*), *V. minima* (Roxburgh) Ohwi and Ohashi, *V. bourneae* Gamble and *V. glabrescens* Marechal, Mascherpa & Stainer are other species in the subgenus *Ceratotropis* reported to occur in India. *V. unguiculata* (L.) Walp. in the subgenus *Vigna* which is of African origin also exhibits much diversity in India, its wild related types do not occur there, the wild types *V. vexillata* (L.) A. Rich. (under subgenus *Plectotropis*) is quite different. *V. pilosa* (Willd.) Baker and *V. marina*

(Burm.) Merr. under sub-genus *Dolichovigna*, *V. luteola* (Jacq.) Benth. under subgenus *Vigna* and *V. grahamianus* (Wt. & Arn.) Verdcourt under subgenus *Macrorhyncha* are also naturalised in some parts of the country (Arora, 1985; Bisht *et al.*, 2002).

Most earlier studies demonstrated species relationships based on a limited number of accessions of individual species and information on intraspecific diversity, particularly in *mungo-radiata* complex, is lacking. Information on intraspecific diversity is essential for effective use of wild species germplasm in crop improvement programmes. The use of wild relatives as sources of new germplasm is well established in breeding programmes for crop improvement on a world wide level, however, the efficiency of introduction of useful traits from wild germplasm such as disease resistance and other agronomic characters into elite cultivars varies greatly. Wild *Vigna* species have great potential for use in crop improvement programmes. Bruchids are serious pest of grain legumes during storage. A wild mungbean accession, *Vigna radiata* var. *sublobata* was reported to be highly resistant to bruchid, *Callosobruchus chinensis* (L.) at the AVRDC (Talekar, 1994). Mungbean yellow mosaic virus (MYMV) has been a major problem in mungbean. The wild species *Vigna radiata* var. *sublobata* is an important source to incorporate resistance to MYMV into cultivated varieties (Singh, 1994). In addition to the landraces and cultivars, the wild species therefore needs to be collected, characterised and conserved carefully for use in crop improvement programmes.

In India, the National Bureau of Plant Genetic Resources (NBPGR) has the major responsibility of collecting, maintaining and conserving the crop plant genetic resources including wild related species. Systematic survey and collection of the wild *Vigna* species occurring in India was undertaken during 1999-2001. In the present communication the information on distribution, habitat and ecology of naturally occurring wild species in *mungo-radiata* complex from different phytogeographical regions of India, their diversity for different morphological characters based on characterisation data and species relationships are discussed.

Material and Methods

Survey and Germplasm Collection

Exploration and collection missions were undertaken during 1999-2001. The areas covered under the exploration

missions include (Figure 1, A-E) the North-western Himalayas (parts of Uttaranchal and Himachal Pradesh); central plateau region (parts of Madhya Pradesh, Chhattisgarh and Maharashtra); parts of Rajasthan, Western Ghats (parts of Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu) and Eastern Ghats (parts of Orissa and Chhattisgarh). Explorations were conducted following a coarse grid survey. Detailed passport data on place of collection, latitude, longitude, altitude, frequency of occurrence, sample type, sampling method, associated vegetation type, habitat/ecology etc., for collected germplasm accessions were recorded.

Germplasm characterisation

The collected germplasm accessions (107 populations) of 5 wild *Vigna* species in *mungo-radiata* complex (Table 1) were grown at the National Bureau of Plant Genetic Resources (NBPGR) Regional Station, Thrissur (Kerala) for detailed morphological characterisation during the 2002 cropping season. The wild species accessions together with ten accessions each of conspecific cultigen types (*V. mungo* and *V. radiata*) were grown both under

field conditions and in earthen pots. Data were recorded for 71 characters, both qualitative and quantitative, based on IPGRI (International Plant Genetic Resources Institute) descriptors with little modifications (Mahajan *et al.*, 2001). Data on qualitative traits were recorded from pot-grown plants whereas field grown plants in Augmented Block Design were used for recording data on quantitative traits. Data for quantitative traits were recorded on five randomly selected individuals per accession. Frequency distribution for qualitative characters and range, mean, and variance for quantitative traits were computed using MSTAT-C statistical package developed at the Michigan State University, USA.

Cladistic and phenetic analysis

The scores for various character states of different accessions were converted to a binary code. The character states X species accessions data matrix was used to calculate the frequency of occurrence of a particular character state in a species. This frequency matrix was used to construct a cladogram based on Fitch optimality criteria. The cladogram obtained was rerooted with *Vigna*

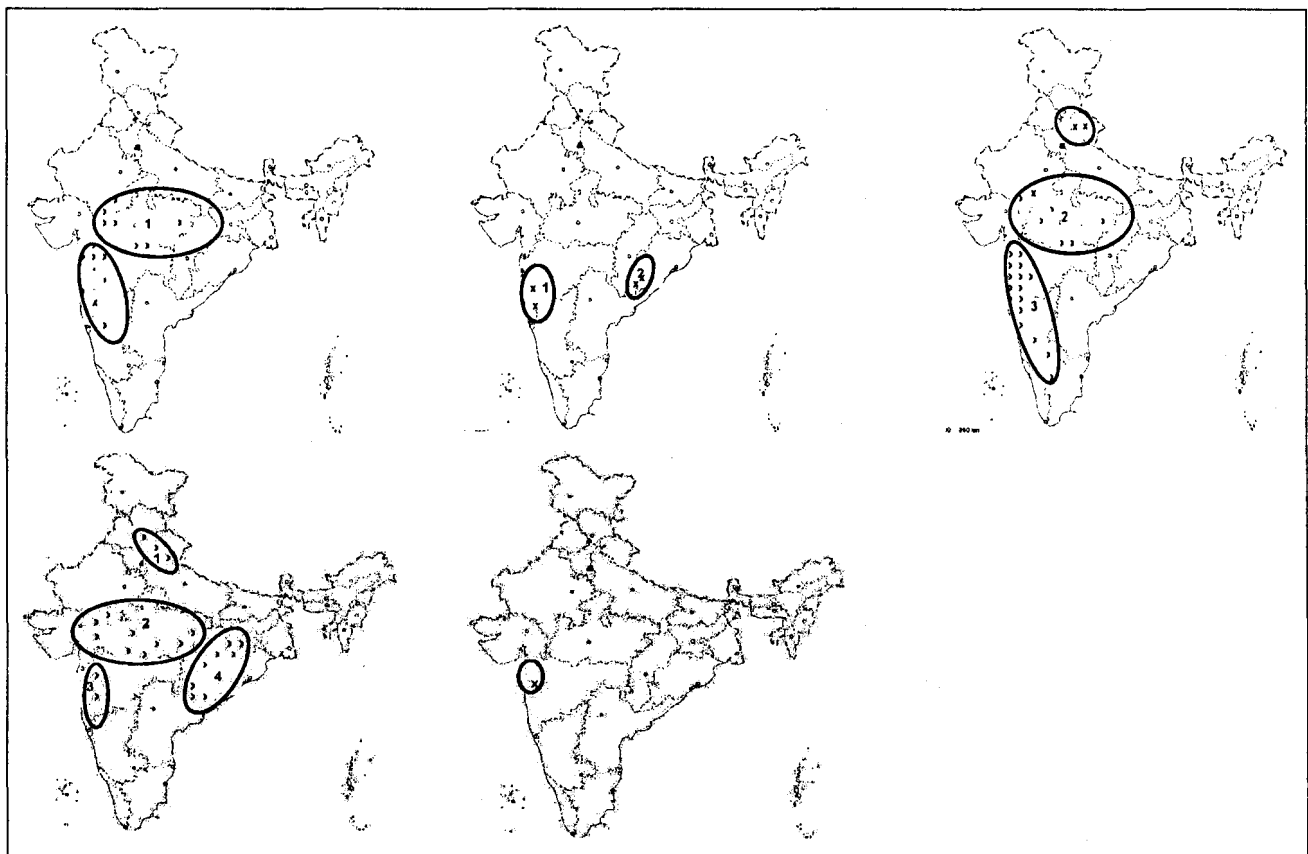


Fig. 1: Distribution of wild *Vigna* species

a) *V. mungo* var. *silvestris*, b) *V. radiata* var. *setulosa*, c) *V. radiata* var. *sublobata*, d) *V. hainiana*, e) *V. khandalensis*

khandalensis as the outgroup since this species is morphologically most distinct in the *mungo-radiata* complex. The branches of the cladogram were reordered using the "Retree" option in "PHYLIP" ver. 3.60 (Felsenstein, 1993). Various alternate positions for each branch were considered, but the cladogram requiring least number of steps was chosen for presentation here.

Principal components analysis

Data on 45 distinct qualitative and quantitative characters (Table 2) were subjected to multivariate analysis using NTSYS ver. 1.80 statistical package (Rohlf, 1992). Multivariate statistics was used to establish species relationships and the pattern of inter- and intra-specific diversity.

The species accessions X qualitative character states data matrix was used to calculate correlations among various character states scored. The correlation coefficient matrix was subjected to eigenvectors analysis. The eigenvectors derived were used to extract the first three most informative principal components. These three components were plotted in both three dimensional and biplot mode in various combinations. Only the biplots of the first two most informative components are presented. Similar principal components analysis (PCA) was also performed for quantitative traits.

Results

a) Distribution, habitat and ecology of wild *Vigna* species in *mungo-radiata* complex

The distribution, habitat, ecology and characteristics of different species are as follows and are illustrated in Figure 1 and Table 1:

V. mungo var. *silvestris*

The species is more closely related to cultivated black gram (*V. mungo*). It is widely distributed in Western Ghat region of Maharashtra with sporadic distribution in Melghat (Maharashtra), Mt. Abu (Rajasthan) and parts of Madhya Pradesh. These habitats were open, steep hill slopes with little shrub or tree cover. Plants in some habitats, particularly in northern part of Western Ghats, were very vigorous, had 6-7 thick pods per inflorescence and seeds fairly large for wild types. Two distinct type of populations were collected from the Western Ghats: i) types twining on shrubs of *Jatropha*, *Ixora* and *Gymnosporia*, near habitations along forest edges with sub-capitate clumps of 6-8 hairy pods each, 3-5 cm long, thick, slightly beaked, 6-8 seeded, seeds dull black with rough surfaces, hilum raised, cracked or split; ii) wild types occurring mainly in disturbed grassy (grazed) patches with *Dicanthium/Sechima/Alpudal/Themeda* and *Centrathemum* species near forest edges in Western Ghats of Maharashtra (Matheran, 800m; Khandala, 800m and Bhimashankar Ghats, 1000m) which were more prostrate, the plants being comparatively less hairy, with 2-4 hairy pods/peduncle, smaller compared to the above type, with less split/ raised hilum. While former type invariably possessed sub-erect, ascending pods, conforming to the variety *V. mungo* var. *silvestris*, the latter type possessed more intermediate characters, with both deflexed and ascending pods or pods more horizontally borne much like the greengram (*V. radiata*).

V. radiata var. *setulosa*

Plants were of sporadic occurrence in Konkan (Western Ghats) – Panhala hills in South Ratnagiri, Kolhapur

Table 1. Geographical distribution of wild species of *V. mungo-radiata* complex and associated vegetation types

<i>Vigna</i> species	Accessions collected	Geographical distribution	Association with major vegetation types
1. <i>V. hainiana</i>	24	Eastern Ghats (parts of Orissa), Central Plateau region (Chhatisgarh, Madhya Pradesh, Maharashtra), North-western Himalayas (Parts of Uttaranchal and Himachal Pradesh)	Sub-tropical wet hills
2. <i>V. khandalensis</i>	1	Western Ghats (Pune district)	Tropical moist evergreen scrub
3. <i>V. mungo</i> var. <i>silvestris</i>	38	Western Ghats and Melghat in Maharashtra, Parts of Rajasthan (Mt. Abu), Central Plateau Region (parts of Madhya Pradesh)	Tropical moist evergreen scrub, Desert scrub, Xerophyllous grasslands
4. <i>V. radiata</i> var. <i>setulosa</i>	11	Western Ghats (parts of Maharashtra), Eastern Ghats (parts of Orissa)	Tropical moist evergreen scrub
5. <i>V. radiata</i> var. <i>sublobata</i>	33	Western Ghats, sporadic distribution in Rajasthan, Madhya Pradesh and North-western Himalayas	Tropical moist evergreen scrub, Hygrophyllous grasslands, Temperate scrub, Montane sub tropical hill Savannah

and the Koraput region in Eastern Ghats (800-1000m elevation). The places were moist but devoid of tree or shrub cover. In Western Ghats, populations occurred in the outskirts of evergreen forests, in the bushy thickets of *Litsea sebifera*, *Memecylon edule*, *Mappia foetida*, *Ixora brachiata*, *Randia brandisii*, *Zizyphus rugosa* and *Carissa congesta*. The plants were stouter and often climbed on hardy tall herbs. The pods were densely hairy, borne deflexed or horizontally on the peduncle, comparatively larger pods (8 cm), higher number of pods/peduncle (8-10), each pod 12-14 seeded, seeds blackish with more linear hilum.

V. radiata var. *sublobata*

Plants are closely related to *V. radiata* (greengram) and have much wider distribution. Collections were made from parts of western Himalayas (600-1800 m), Western Ghats (100-600m), Madhya Pradesh (500-800m), Rajasthan (400-600m). Maximum distribution was recorded in the northern part of Western Ghats. Disjunct and sporadic distribution occurs in Nilgiris and southern parts of Western Ghats. In the North-western region *sublobata* types were associated with *Heteropogon contortus*, *Alpura mutica*, *Themeda triandra* and *Aeschynomene indica* and also on sub-temperate forest undergrowth predominantly on eroded, exposed slopes. Habitats, in general, were open, sloppy grasslands on waste places, forest trails and steep hill sides. The plants had thinner stems, smaller pods and seeds as compared to *V. radiata* var. *setulosa*.

V. hainiana

The species has a wider distribution; collections were made from Madhya Pradesh, Orissa, Chhatisgarh, parts of Rajasthan, Uttaranchal and Himachal Pradesh ranging from 500 to 2000 m elevations. The habitats of this species are open dry places, often loose rocky mounds, steep sides of hill roads. Under favourable dry habitat, free from competition in rocky hill slopes, dense populations covering a considerable area were found.

V. khandalensis (*V. grandis*)

Sparsely distributed populations of this endemic species could be located in Pune district (Purandar hills, Bhimashankar hills and Khandala, 600-800m elevation). Habitat of species is open, humid hill slopes. A few populations of this species were also collected from paddy field bunds along the hill slope on way to Bhimashankar hill in Pune. This species is distinct from other Asian *Vigna* species as it is tall, erect, thick

stemmed, herbaceous type with large foliaceous stipules. Racemes close, usually 2-6 pods per peduncle, pods up to 8 cm long, sub-erect, thick, glabrous, 8-10 seeded, bold, brownish-black, rough, with minute, sub-split partially raised hilum.

Figure 1 (A to E) shows the distribution of wild *Vigna* species in the *mungo-radiata* complex. The biogeographical considerations and association of wild *Vigna* species with major vegetation types is presented in Table 1. Ecologically, wild *Vigna* species in the *mungo-radiata* complex occur in different associations as components of the herbaceous and grassy undergrowth or are seen twining on bushes in scrub vegetation. More density occurs in the moist tropical and sub-tropical zones. Maximum species were concentrated in the northern parts of the Western Ghats. These include 2 endemic types viz. *V. khandalensis* and *V. radiata* var. *setulosa*. The distributional range of these overlap with *V. radiata* var. *sublobata*, *V. mungo* var. *silvestris* and other *Vigna* species including, *V. dalzelliana* and *V. vexillata*. *V. khandalensis* is very sparsely distributed. In the Eastern Ghats, *V. hainiana* is the most widespread species. *V. radiata* var. *setulosa* being more of sporadic distribution. In the western Himalayas (medium elevation zone, upto 1800 m), *V. hainiana* and *V. radiata* var. *sublobata* exhibit sporadic distribution. Paucity of species diversity occur in *mungo-radiata* complex in the north-western plain zones with sporadic distribution of other *Vigna* species, *V. trilobata* and *V. aconitifolia*. In the Deccan plateau region, sporadic distribution of *V. hainiana* and *V. trilobata* occurs.

Sporadic distribution of *V. radiata* var. *sublobata*, *V. mungo* var. *silvestris*, *V. hainiana* together with *V. aconitifolia* and *V. trilobata* was recorded in the western drier parts of the country, parts of Rajasthan (Mt. Abu, Chittorgarh, Udaipur, Sirohi), MP (Dhar, Mandu) and adjoining Maharashtra (Melghat).

b) Diversity analysis and species relationships in *mungo-radiata* complex

The common key distinguishing features of wild species under *mungo-radiata* complex are epigeous cotyledons; sessile first and second leaves; predominantly climbing growth habit; moderate to dense pubescence of various plant parts- stem, petiole, leaves and pods; straight and round pods, borne horizontally or deflexed; mottling on seed surface slight to none and absence of lustre on seed surface. All the species had flower colour in various shades of yellow. Between species variation,

Table 2. Important descriptors used for characterisation of wild *Vigna* species germplasm in *mungo-radiata* complex

S.No.	Characters/Descriptors	Descriptor states
<i>Qualitative descriptors</i>		
1.	Seed germination habit	1. Epigeal, 2. Hypogeal
2.	Attachment of primary leaves (at two leaf stage)	1. Sessile, 2. Sub-sessile, 3. Petiolate
3.	Growth habit (recorded at first pod maturity)	1. Erect, 2. Semi-erect, 3. Spreading, 4. Semi-prostrate, 5. Prostrate, 6. Climbing
4.	Leafiness (at 50% flowering)	1. Sparse, 2. Intermediate, 3. Abundant
5.	Leaf pubescence	1. Glabrous, 2. Very sparsely pubescent, 3. sparsely pubescent, 4. Moderately pubescent, 5. Densely pubescent
6.	Petiole pubescence	1. Glabrous, 2. Pubescent, 3. Moderately pubescent, 4. Densely pubescent
7.	Lobing of terminal leaflet (at first pod maturity)	1. Unlobed, 2. Shallow, 3. Intermediate, 4. Deep 5. Very deep
8.	Terminal leaflet lobe shape	1. Lanceolate, 2. Broadly ovate, 3. Ovate, 4. Rhombic, 5. Others
9.	Stipule size	1. Small, 2. Medium, 3. Large
10.	Stipule shape	1. Ovate; 2. Lanceolate, 3. Others
11.	Stem pubescence	1. Glabrous, 2. Sparsely pubescent, 3. Moderately pubescent, 4. Highly pubescent
12.	Raceme position (at first pod maturity)	1. Mostly above canopy, 2. In upper canopy, 3. Throughout canopy
13.	Calyx colour	1. Green; 2. Purplish green, 3. Greenish purple, 4. Others
14.	Corolla colour	1. Yellow, 2. Greenish yellow, 3. Yellowish green, 4. Green-purplish yellow, 5. Others
15.	Bracteole size	1. Small, 2. Intermediate, 3. Large
16.	Bracteole shape	1. Linear, 2. Lanceolate, 3. Others
17.	Flowering period	1. Asynchronous, 2. Intermediate, 3. Synchronous
18.	Pod attachment to peduncle	1. Erect, 2. Horizontal, 3. Horizontal-pendent, 4. Pendent, 5. Others
19.	Pod pubescence	1. Glabrous, 2. Sparsely pubescent, 3. Moderately pubescent, 4. Densely pubescent
20.	Pod curvature	1. Straight, 2. Slightly curved, 3. Curved (sickle shaped)
21.	Pod beak shape	1. Pointed, 2. Blunt, 3. Others
22.	Constriction of pod between seeds	1. Absent, 2. Slight, 3. Pronounced
23.	Pod cross section	1. Semi flat, 2. Round, 3. Others
24.	Seed shape	1. Globose, 2. Ovoid, 3. Narrowly ellipsoid, 4. Cubical to oblong, 5. Kidney shaped, 6. Drum shaped, 7. Others
25.	Seed colour	1. White, 2. Cream, 3. Light brown, 4. Intermediate brown, 5. Dark brown, 6. Grey, 7. Mottled grey, 8. Mottled brown, 9. Mottled cream, 10. Light cream, 11. Green brown, 12. Chocolate, 13. Black
26.	Lusture on seed surface	1. Absent, 2. Present
27.	Mottling on seed surface	1. Absent, 2. Slight, 3. Intermediate, 4. Heavy
28.	Hilum shape	1. Concave, 2. Plain, 3. Convex, 4. Others
<i>Quantitative Descriptors</i>		
29. Terminal leaflet length (cm), 30. Terminal leaflet width (cm), 31. Petiole length (cm), 32. Plant height (m), 33. Days to flowering, 34. Flower bud size (cm), 35. No. of flower per raceme, 36. Peduncle length (cm), 37. No. of pods per peduncle, 38. Days to maturity, 39. Pod length (cm), 40. No. of pods per plant, 41. No. of seeds per pod, 42. 100-seed weight (g), 43. Seed size (mm ²), 44. Hilum length (mm), 45. Yield per plant (g)		

except for the two characters, number of pods per plant and seed yield, was significantly greater than within species variation for most of the quantitative characters.

Table 3 lists the inter- and intra-specific morphological variation in different wild *Vigna* species populations in *mungo-radiata* complex. All the species, except *V. khandalensis*, showed greater homology in growth habit and other vegetative parts. These species, however, differed in pubescence of various plant parts, and pod and seed characteristics. *V. hainiana* populations had exceptionally small flowers and seeds as compared to

the other species in the group. Within species variation was more prominent in *V. mungo* var. *silvestris* and *V. radiata* var. *sublobata*. *V. khandalensis* was remarkably distinct from other species by having erect plant habit, large foliaceous stipules and broad leaflets. In flower and pod characteristics it resembled with both *V. mungo* and *V. radiata*.

Table 4 lists the mean values of 17 important quantitative traits on cultigen types and conspecific wild species in *mungo-radiata* complex. Table 5 lists the comparative measurement of mean, range and variation

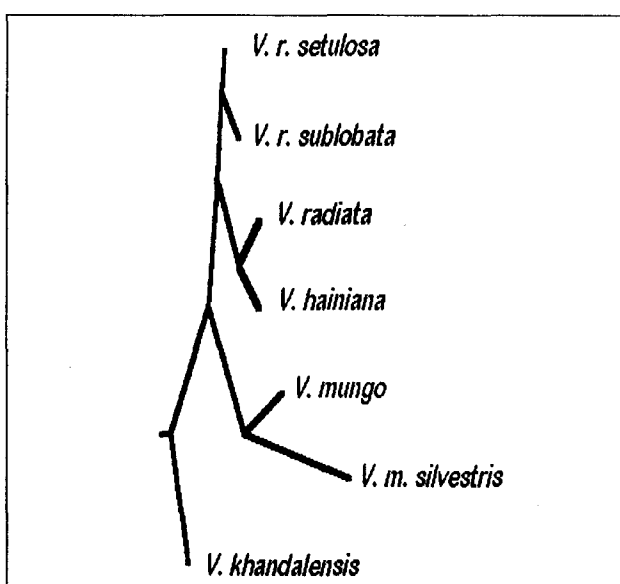
Table 3. Inter- and intra-specific variation in wild *Vigna* species in the *mungo-radiata* complex of subgenus *Ceratotropis*

Species	Interspecific variation	Intraspecific variations
<i>V. hainiana</i>	Climbing growth habit, petioles and peduncles clothed with deflexed, greyish or greenish brown hairs. Early flowering/ maturing; small flowers; more number of pods per peduncle; thin round glabrous to slightly hairy pods; comparatively smaller seeds, blackish grey or brown, low 100- seed weight.	The population revealed greater homology for floral organs. Variation between populations observed for terminal leaflet size, plant height, flower bud size, pubescence of various plant parts, seed shape and mottling of seed surface.
<i>V. mungo</i> var. <i>silvestris</i>	More closely related to urdbean (<i>V. mungo</i>). Medium maturity; relatively low number of flowers per raceme and fewer pods per peduncle; highly pubescent pods; pods ascending or deflexed; relatively bold seeds as compared to other species of the group and low number of seeds per pod usually varying from 4-8.	Two distinct types of populations were noticed: a) highly twining/climbing types with low branching potential with sub-capitate clumps of of 6-8 hairy pods, sub-erect or ascending, each 3-5 cm long, thick slightly beaked, 3-6 seeded; seeds dull black with rough surface; hilum much raised, cracked or split; some population have very high yield potential b) more prostrate types; low plant height; plants being comparatively less hairy with 2-4 hairy pods peduncle, both deflexed and ascending, each 6-8 seeded; seeds blackish dull, smaller to above type, with less split/raised hilum.
<i>V. radiata</i> var. <i>sublobata</i>	Loose sub-capitate heads, thinner, sparsely hairy or glabrous pods as compared to <i>setulosa</i> types, borne deflexed or horizontally on the peduncle.	Between population variation was observed for leafiness, leaf pubescence, lobing of terminal leaflets, leaflet shape, days to flowering, raceme position, seed shape and size.
<i>V. radiata</i> var. <i>setulosa</i>	Early flowering/maturing; comparatively longer hairy pods, borne deflexed or horizontally; higher number of pods per peduncle, each with 12-14 seeds; seed blackish black with more linear hilum.	Populations varied for seed shape and mottling of seeds. Variation was also observed for flower bud size, peduncle length and seed size.
<i>V. kandalensis</i>	It is characterised by erect growth habit and thick stem; shows more akinness to blackgram with its close raceme of 3-6 pods per peduncle; pods 6-7 cm long, sub-erect, medium thick; glabrous/ minutely strigose (like greengram); 8-10 seeds per pod; seeds comparatively bold, blackish brown, rough, occasionally mottled with minute sub-split partially raised hilum.	

of 8 quantitative traits of cultigen types and conspecific wild species in the *mungo-radiata* complex of subgenus *Ceratotropis*. It is evident that the range of variation particularly for number of pods per plant and yield per plant is more for wild species than the cultigen types. The conspecific cultigen types were however more robust with erect growth habit and recorded three to five fold increase in seed size and seed weight.

The cladogram (Fig 2) appears to contain two clades, one comprising the collections *V. radiata* var. *setulosa*, *V. radiata* var. *sublobata*, *V. radiata* (cultigen) and *V. hainiana* and the second clade had only *V. mungo* (cultigen) and *V. mungo* var. *silvestris*. From the cladogram it is very much apparent that the variation within *V. hainiana* collections is closer to *V. radiata* group. *V. kandalensis* occupies the third clade.

The principal components analysis ordination of the species in *mungo-radiata* complex (Fig. 3) shows

Fig. 2: Cladogram of wild *Vigna* species and conspecific cultigen types in *mungo-radiata* complex

that *V. radiata* var. *sublobata* and var. *setulosa* are close in PCA ordination forming a distinct overlapping group with the conspecific cultigen types, *V. radiata*. *V. mungo* var. *silvestris* populations formed two distinct groups, quite apart in ordination. Only one group overlapped with cultigen types, *V. mungo*. Majority of the *V. hainiana* populations formed a distinct group and showed more homology among its populations. However, overlapping populations of different species in the in PCA ordination were also recorded (Fig. 3).

The PCA performed on the quantitative traits revealed that the first three components accounted for 57.27%

variation (Table 6). The Table also shows the characters with greater weightage in each of the three most informative principal components.

Discussion

Wild *Vigna* species occupy over 16 different vegetation types, largely biotic/bio-edaphic in status (Arora, 1985). More diversity occurs in the moist tropical/sub-tropical habitats than in the hot arid or cold temperate zones; the tropical evergreen scrub, the montane sub-tropical hill savannah, and the mesophyllous grasslands support as many as 12 out of 16 species occurring in India.

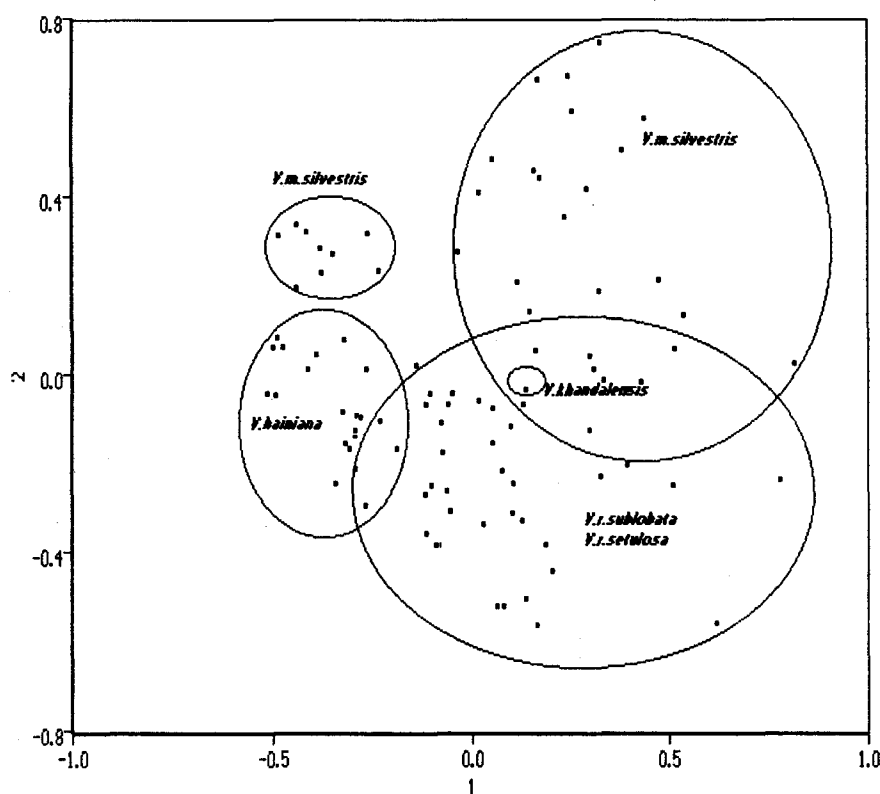


Fig. 3: Principal components analysis ordination of germplasm accessions of wild *Vigna* species and conspecific cultigen types in mungo-radiata complex

Table 4. Means of selected quantitative characters* of wild *Vigna* species and conspecific cultigen types in mungo-radiata complex

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
<i>V. mungo</i> (cultigen)	13.28	8.63	13.74	1.27	47.36	0.63	6.63	7.48	4.63	77.09	4.42	63.97	6.54	4.03	16.99	2.15	6.16
<i>V. m. silvestris</i>	9.52	6.64	10.49	1.96	65.40	0.64	3.93	8.72	2.46	94.78	3.77	151.61	7.71	1.60	8.89	2.05	4.65
<i>V. radiata</i> (cultigen)	8.71	6.60	8.52	0.34	44.50	0.81	4.71	7.60	3.57	60.00	6.61	49.79	10.92	2.70	12.07	1.83	1.34
<i>V. r. setulosa</i>	11.11	9.73	10.76	2.04	49.43	0.68	5.85	8.94	2.86	65.43	5.60	25.17	10.43	1.22	6.54	1.22	2.05
<i>V. r. sublobata</i>	7.75	6.60	9.48	1.51	60.13	0.63	5.90	9.47	3.31	78.38	4.80	91.30	10.10	1.16	6.63	1.43	2.13
<i>V. hainiana</i>	10.61	8.97	11.32	2.42	49.83	0.26	6.16	6.63	5.16	74.50	3.93	159.06	9.67	0.68	4.52	1.14	3.26
<i>V. khandalensis</i>	13.43	12.67	10.10	1.98	155.00	0.60	4.00	17.50	5.00	175.00	5.66	15.33	10.00	4.08	15.22	1.52	2.29

*1: Terminal leaflet length, 2: Terminal leaflet width; 3: Petiole length, 4: Plant height; 5: Days to flowering, 6: Flower bud size, 7: No. of flowers per raceme, 8: Peduncle length, 9: Pods per peduncle, 10: Days to maturity, 11: Pod length, 12: Pods per plant, 13: Seeds per pod, 14: Seed weight, 15: Seed size, 16: Hilum length, 17: Yield per plant

Table 5. Mean, range* and variance for important quantitative traits of cultivated and wild *Vigna* species in the *mungo-radiata* complex

Character		<i>V. hainiana</i>	<i>V. mungo</i>	<i>V. m. silvestris</i>	<i>V. radiata</i>	<i>V. r. setulosa</i>	<i>V.r. sublobata</i>	<i>V. kandalensis</i>
Plant height	Mean	2.42	0.75	1.96	0.54	2.04	1.51	1.98
	Range	1.00-6.67	0.44-1.95	0.95-3.18	0.24-0.83	1.37-2.62	0.40-3.01	–
	CV	57.80	25.90	29.08	61.70	20.00	39.70	–
Days to flowering	Mean	49.83	47.36	65.40	44.50	49.43	60.13	155.00
	Range	41.00-64.00	31.00-73.00	36.00-139.00	34.00-93.00	30.00-78.00	34.00-147.00	–
	CV	15.70	35.30	32.60	13.32	37.00	39.70	–
Days to maturity	Mean	75.50	77.09	94.78	68.00	65.43	78.38	175.00
	Range	67.00-90.00	67.00-117.00	68.00-158.00	58.00-94.00	54.00-83.00	51.00-175.00	–
	CV	10.90	20.10	23.00	9.50	14.60	31.00	–
No. of pods per plant	Mean	159.06	63.97	151.61	49.79	25.17	91.30	15.33
	Range	27.00-418.00	18.60-94.00	6.00-697.00	8.66-111.00	10.00-40.57	5.74-289.00	–
	CV	81.40	19.70	100.80	71.20	44.80	91.00	–
100-seed weight	Mean	0.68	4.03	1.60	2.90	1.22	1.16	4.80
	Range	0.53-0.84	2.33-5.10	1.20-2.54	1.57-4.06	10.43-2.22	0.55-2.40	–
	CV	14.70	11.90	21.30	25.50	47.50	41.70	–
Seed size	Mean	4.52	16.99	8.89	12.07	6.54	6.63	15.22
	Range	0.96-5.51	14.09-20.82	5.47-14.40	8.46-15.99	1.02-9.48	1.83-11.53	–
	CV	25.80	12.60	25.00	14.80	42.80	34.40	–
Hilum length	Mean	1.14	2.15	2.05	1.83	1.22	1.43	1.52
	Range	0.59-1.83	1.86-2.46	1.47-3.04	0.72-8.55	0.42-1.91	0.22-2.00	–
	CV	30.00	7.90	14.60	18.00	36.00	22.30	–
Yield per plant	Mean	3.26	6.16	4.65	5.34	2.05	2.13	2.29
	Range	0.81-7.88	1.67-9.88	0.34-60.90	0.72-8.85	0.30-5.61	0.30-4.72	–
	CV	58.70	41.30	228.80	41.79	77.10	60.00	–

* Range (minimum-maximum), CV= Coefficient of Variation

Table 6. Variation explained by each eigenroot and important characters with maximum weightage in Principal Components Analysis of wild *Vigna* species in *mungo-radiata* complex

PC axes	Total variation explained		Important characters with maximum weightage
	%	Cumulative	
I	28.41	28.41	Terminal leaflet width, terminal leaflet length, petiole length
II	16.94	45.35	Seed size, seed weight, days to maturity, days to flowering
III	11.92	57.27	Seed yield, peduncle length, no. of pods per plant, plant height

About 9 species are concentrated in the northern parts of the Western Ghats. Among the two widely distributed species in *mungo-radiata* complex, *V. mungo* var. *silvestris* and *V. radiata* var. *sublobata*, the former showed greater intraspecific variability as compared to the latter. Two distinct population types in *V. mungo* var. *silvestris*, were noticed. The highly twining type populations had more number of pod bearing clusters with 6-8 hairy sub-erect or ascending pods. The prostrate type populations with low plant height had 2-4 hairy pods per peduncle, both deflexed and ascending. These two population types were clearly distinct in PCA ordination (Fig 3) based on characterisation data and only one group overlapped with cultigen types, *V. mungo*.

V. radiata var. *sublobata* populations were comparatively more homogeneous. *V. radiata* var. *setulosa*, with restricted distribution, is closely related to var. *sublobata*. The *setulosa* types possessed comparatively larger and densely hairy pods. *V. hainiana* populations were of sporadic occurrence in Western Ghats. *V. hainiana* shows akinness to both *V. mungo* and *V. radiata* wild types. In pod characteristics *V. hainiana* resembles *V. radiata* var. *sublobata*. It however, differed from the latter in having flexuous stems, large peltate stipules, long greyish or greyish brown hairs on stem and petioles (like *V. mungo* var. *silvestris*). Morphologically this species is more primitive than wild related species of *V. radiata* and *V. mungo* with comparatively small flowers and very

small seeds. *V. khandalensis*, endemic to India with sporadic distribution in northern parts of Western Ghats, is quite distinct from other Asian *Vigna* species. It is tall, erect, thick stemmed and shrub like with large foliaceous stipules. However, it shows morphological akinness to both *V. mungo* (close raceme) and *V. radiata* (sub-erect, glabrous/ minutely strigose medium thick pods). About 10 species occur in the Nilgiris and adjoining parts in Southern India with sporadic distribution of *V. radiata* var. *sublobata*.

In the Eastern Ghats, 5 or 6 species exhibit overlapping distribution. *V. hainiana* is the most widely distributed species in the *mungo-radiata* complex. *V. radiata* var. *setulosa*, has sporadic distribution in higher elevations (more than 800m) around Koraput district in Orissa. In, the Western Himalayas, *V. hainiana* and *V. radiata* var. *sublobata* were of sporadic occurrence. Paucity of species diversity was observed in the north-western plain zones extending eastwards to the Indo-Gangetic belt.

From an exploration standpoint, pockets of species diversity exhibiting sympatric and disjunct distribution are important, as is also their collection from ecologically variable sites within their range of distribution (Arora, 1985). More variability was collected in the widely distributed taxa. More collection efforts are needed in *V. radiata* var. *sublobata* particularly from Eastern Ghats, north-eastern region and Southern parts of Western Ghats (disjunct distribution occurs) which are less represented in the present collection. Sporadic pockets of wild species diversity which could not be surveyed under the present programme, particularly the north-eastern region, the Chhota Nagpur region, and from sites where wild types occur in proximity to the cultivated types.

In order to collect more infraspecific variation in *mungo-radiata* complex, fine grid sampling needs to be done in areas where diverse populations overlap. The overlapping populations are clearly reflected in the PCA ordination (Fig 4) based on characterisation data. More populations exhibiting greater morphological variations need to be collected from areas of higher species diversity in order to capturing higher genetic diversity in these species. These collections would have greater utility in crop improvement programmes as well as in evolutionary studies (Arora *et al.*, 1973; Chandel *et al.*, 1984; Dana, 1966; Jain and Mehra, 1980; Mayazaki, 1982; Bisht *et al.*, 2002)). Serious efforts also need to be made to collect as much variation as

possible of *V. khandalensis*, a species with very restricted distribution in the disjunct high elevation areas in the northern parts of Maharashtra and adjoining Gujarat. Some areas around Purandar hill and Bhimashankar hill might even be developed as gene sanctuary for this endemic species. Extensive fine grid survey and intensive collection efforts, starting from Mt Abu (Rajasthan) to Nilgiris (Southern India) needs to be undertaken as the Western Ghats ranges are the macrocentre of origin and diversity particularly for most of the species in the *mungo-radiata* complex.

The wild species has a great potential for use in crop improvement programmes. Successful hybridization between *V. radiata* and *V. glabrescens*, resulted into four pure lines carrying moderate resistance to thrips (AVRDC, 1990). Srinivas *et al.* (1999) attempted inter-specific hybridization between mungbean and its related *Vigna* species. Pod setting percentage was high when *V. radiata* was female parent. The cross *V. radiata* x *V. radiata* var. *sublobata* gave the highest pod setting (26.1%). Inter-specific crosses combined with embryo rescue were successful when male parents were *V. radiata* var. *sublobata*, *V. mungo*, *V. mungo* var. *silvestris*, *V. umbellata* (wild), *V. angularis* and *V. glabrescens*, but was not successful in crosses involving mothbean (*V. aconitifolia*).

In common with most grain legume crop species, the wild related species do not form a particularly extensive or accessible genetic resource. Many of these wild species, *Vigna radiata* var. *sublobata*, *V. mungo* var. *silvestris*, *V. khandalensis*, *V. trilobata*, and *V. hainiana* are gathered for their ripe seeds, which are boiled and eaten (unripe seeds are also eaten raw) by the tribal/local communities during famines and their over exploitation has threatened their preponderance in natural habitats. More variability in wild conspecific forms is to be collected, characterised and conserved carefully in addition to the fullest range of landraces and cultivars. Greater exploitation of the conspecific wild species with valuable characters needs to be made to make extended cultivation economically attractive (Smartt, 1990). Some populations of *V. mungo* var. *silvestris*, *V. radiata* var. *sublobata* and *V. radiata* var. *setulosa* with valuable characters like more number of pod bearing clusters and pods per cluster have great agronomic potential for use in crop improvement programmes beside the resistance/ tolerance to biotic stresses. Sources of resistance available in *Vigna radiata*

var. sublobata (Singh, 1994) needs to be exploited more vigorously with the help from biotechnological tools.

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Wild Useful Species of *Allium* in India – Key to Identification

Anjula Pandey and Ruchira Pandey

National Bureau of Plant Genetic Resources, New Delhi-110 012

The present investigation elucidates systematic study on wild useful *Allium* species in India. It provides an artificial key primarily based on bulb and leaf morphological characters for identification of 26 species.

Key words: Artificial key, Bulb, Identification, Leaf, Vegetative characters

The genus *Allium* (family Alliaceae) is widely distributed in the temperate and alpine regions of Himalaya. Over 750 species are confined chiefly to northern temperate and alpine zones of the world (Jones and Mann, 1963; Stearn, 1992). Of about 30-35 species reported from India, majority of wild species are known to occur as semi-domesticated/ semi-protected and wild component of native flora confined to the temperate and alpine regions of India (Negi *et al.*, 1991, Sharma *et al.*, 1996). Among wild useful species *A. carolinianum*, *A. consanguineum*, *A. humile*, *A. przewalskianum*, *A. rubellum*, *A. seminovii*, *A. stracheyi*, *A. victorialis* and *A. wallichii* are locally used for edible leaves, bulbs and tuberous roots (Shah and Joshi, 1970; Negi and Gaur, 1991; Chandel and Pandey, 1992; Chaurasia and Singh, 1996-2001). Indiscriminate harvest, large-scale use and commercialization of wild species from their natural habitat for edible, flavouring, ornamental and medicinal value has resulted in population decline in several wild *Allium* species (Negi and Gaur, 1991).

Wild *Allium* species exhibit significant diversity in morphological and reproductive characters. All species do not flower or produce seeds under unfavourable conditions. The vegetative propagules (bulb, rootstock, rhizomatous base, bulbils, etc.) remain persistent for longer period, survive under adverse conditions and are collected even after completion of the vegetative and reproductive phase.

Baker (1874) classified genus *Allium* into seven groups based on characters of bulb, filaments, spathe and direction of perianth-segments in the expanded flower. Hooker (1893) described wild species as the component of natural ecosystem and classified them under different sections and groups primarily based on leaf and floral morphology. Despite several valuable works published thereafter, the taxonomic confusion pertaining to classification, correct nomenclature and synonymy continued to exist and remained complicated (Baker,

1874; Hooker, 1893; Jones and Mann, 1963; Rabinowitch and Brewster, 1990; Gregory *et al.*, 1998).

While gathering wild species, the collector encounters difficulty in identification and authentication of species (Guarino *et al.*, 1995). The germplasm identification in wild *Allium* species, primarily based on the vegetative parts is, difficult due to non-availability of characters in collected material. Lack of information on diagnostic characters, in collected material, in herbarium specimens and, in published literature, is the principal bottleneck for taxonomic studies. The present investigation elucidates systematic studies primarily based on bulb and leaf morphological characters and includes an artificial key for identification.

Materials and Methods

The bulb shape (if formed), scale characters (colour and texture) and leaf characters (flat or fistular) were regarded as important characters for identification in the present study. Data on scape (hollow or solid), flower colour, plant odour when crushed (onion or garlic type) and additional data on floristic records, published treaties, exploration and herbarium records, and field survey information have been used for further validation of species.

Studies were carried out using the material received for identification in the National Herbarium of Cultivated Plants (NHCP), for conservation in Tissue Culture and Cryopreservation Unit (TCCU), Field genebank and herbarium specimens available in NHCP, National Bureau of Plant Genetic Resources, New Delhi. The vegetative propagules were raised in the nethouse and observations on the bulb/ rhizome and leaf characters were recorded. The term bulb has been used in the key to denote true bulbs or under-developed structures formed as bulbous bases. The characters of leaf and bulb scale are recorded for a fully matured plant. An artificial key has been prepared as an aid in identification of 26 wild useful *Allium* species.

Key to wild useful species

Allium species were distinguishable on the basis of above characters. Based on the systematic work undertaken, an artificial key for identification has been developed and presented below:

1. Conspicuous rhizome/ rootstock present

2. Bulb well developed

3. Scale membranous

Lf- flat, stout, shorter than scape; Bl- solitary, oblong seated on creeping rootstock, Sc- membranous, lilac red — *A. carolineanum*

Lf- flat, linear, keeled; Bl- larger, elongated, pear shaped, clustered on rhizomatous rootstock; Sc- thick, membranous, reddish- brown

— *A. consanguineum*

Lf- linear; Bl- solitary/clustered on short perpendicular rootstock; Sc- hyaline, membranous, dark coloured — *A. platyspathum*

Lf- flat, narrowly linear, tip rounded; Bl- narrowly ovoid, small, clustered, seated on long neck; Sc- membranous, dark brown — *A. stracheyi*

Lf- narrowly linear, hollow, trigonous (sharply angled); Bl- clustered on rootstock, ovoid-oblong; Sc- membranous, white-grey — *A. chinense*

Lf- linear, fleshy; Bl- ovoid, clustered on rootstock; Sc- hard, membranous, chestnut brown

— *A. thomsonii*

3 Scale reticulate

4 Leaf fistular

Lf- fistular, round in section; Bl- clustered, cylindrical, elongated; Sc- finely reticulate, rusty brown — *A. przewalskianum*

4 Leaf flat

Lf- flat, narrowly linear, obtuse, stout; Bl- elongated, narrow, seated on oblique rootstock; Sc- reticulately fibrous, brown-red; bulbils present

— *A. auriculatum*

Lf- flat, narrow, minutely serrulate; Bl- clustered on rhizome, cylindrical, elongated, conical; Sc- leathery (rigid), coarsely reticulate

— *A. oreoprasum*

Lf- flat, linear; Bl- sub-cylindrical, inserted on a stout cylindrical rootstock; Sc- densely fibrous, reticulate, brown — *A. schrenki*

2 Bulb poorly developed / not developed

5 Leaf fistular

Lf- filiform, fistular; Bl- small, ovoid, solitary, narrow, seated on narrow but distinct rhizome; Sc- membranous, red-brown — *A. roylei*

Lf- thin, fistular, round in section; Bl- clustered, narrow, not well developed, seated on short, vertical rhizome; Sc- membranous; bulbils rarely present

— *A. schoenoprasum*

Lf- narrow, channeled; Bl- not developed, clustered, cylindrical, seated on root stock; Sc- paralleled fibre

— *A. sikkimense*

5 Leaf flat

6 Bulb scale membranous

Lf- ensiform, keeled; Bl- poorly developed, clustered on root stock, roots- thick, fibrous; Sc- torn membranous sheath — *A. wallichii*

Lf- linear, membranous, turns reddish on drying; Bl- poorly developed on erect creeping rootstock, roots- thick, fleshy and edible; Sc- whitish-light brown, membranous — *A. hookeri*

Lf- linear; Bl- poorly developed, elongated, clustered on rootstock; Sc- membranous, purple-pink — *A. cernuum*

6 Bulb scale fibrous

Lf- petioled, elliptical-lanceolate, obtuse-acute; Bl- subconic-subcylindrical, clustered on oblique rootstock; Sc- reticulately fibrous

— *A. victorialis*

Lf- flat, linear; Bl- poorly developed, elongated, clustered on stout tuberous roots; Sc- fibrous

— *A. fasciculatum*

Lf- flat, obtuse, blunt tipped; Bl- cylindrical-subcylindrical; Sc- fibrous — *A. humile*

Lf- keeled below, flat above; Bl- elongated, cylindrical seated on white fibrous root stock; Sc- reticulately fibrous, pale, grey, brown or white

— *A. tuberosum*

1 Conspicuous rhizome/ rootstock absent

7 Leaf flat, linear

8 Leaf keeled

Lf- linear, gradually acuminate, keeled; Bl- small, narrow; Sc- membranous (a beautiful species)

— *A. macranthum*

Lf-filiform, keeled from below, Bl-clustered/solitary, ovoid-oblong, elongated, produced on longneck; Sc- finely reticulately fibrous, brown

— *A. griffithianum*

Lf- linear, keeled; Bl- well developed, ovoid-oblong, cloves as in garlic but of two sizes, bulbils on bulbs; Sc-membranous, white/ hyaline

— *A. ampeloprasum*

8 Leaf not keeled

Lf-linear-lanceolate, spear shaped; Bl:small, ovoid; Sc: membranous, grey; plant having garlic smell

— *A. loratum*

Lf-linear, oblong-lanceolate; Bl- narrow, subglobose ovoid; Sc-membranous — *A. atropurpureum*

7 Leaf fistular

Lf- fistular, acute with long sheath; Bl- perennial, small, clustered, cylindrical, covered with old fibrous sheath; Sc- membranous, whitish purple-pink

— *A. semenovii*

(Lf- leaf; Bl- bulb; Sc- scale)

Conclusion

The collected germplasm of wild species lacks data on key identification features as characters of leaf, bulb, scape (hollow or solid) and flower. This becomes a major limitation in identification of germplasm of wild *Allium* species. The process of identification is further delayed due to the following reasons:

- While collecting the germplasm, it is not always possible for a collector to prepare an ideal herbarium specimen.
- Characters of leaf (hollow/ flat), bulbs, rhizomes, flower, plant odour etc. are generally lost or modified in collected material and herbarium specimens when it reaches the identifier.
- Germplasm collectors usually separate the bulbs from whole plant while assembling, sorting and indexing the material in the base camp.
- Generally many wild species do not produce flowers/ seed under unfavorable conditions. Lack of this data causes further difficulty in carrying out systematic work.
- Due to lack of ecological, distributional or agronomic data, authentication/ identification is difficult particularly in case of the wild/ related species.

To facilitate process of identification/ authentication, it is desirable that collector should furnish the following information:

- Special notes on passport information on perishable features of plant including bulb, leaf and scape characters.
- Accompanying data on ephemeral parts, especially flower, scale colour, etc.
- Range of variability of germplasm, even if not collected, must be mentioned in the accompanied data in order to have bird-eye view on the population.
- Photographic details of all parts (field view, fresh harvest, leaf, flowers, bulb scale colour, etc.).

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Preliminary Investigation of Some Plants of Ornamental Value from Wild Flora of Shimla

K Pradheep, JC Rana, Archana Singh and VD Verma

National Bureau of Plant Genetic Resources Regional Station, Shimla-171 004 (Himachal Pradesh)

Around 90 plants of various ornamental utility viz. annuals, herbaceous perennials, climbers, shrubs trees, hedges, foliage and bulbous plants, etc. were shortlisted apart from those suited to rock garden and dry flower arrangements. The category 'herbaceous perennial' had a maximum number of plants followed by shrubs. Plants such as *Delphinium denudatum* wall., *Spermatidictyon suaveolens* Roxb., *Reinwardtia indica* Dumort., *Caryopteris wallichiana* Schuer and *Buddleia paniculata* Wall., seemed to suit to the requirement of cut flower. Most of the weedy grasses can find a place in dry flower arrangements. It became visible that almost all kinds of ornamentals are available over different seasons from these native wild plants. Emphasis can be given for those plants flowering all the year round, during lean season and over longer period. Problems related to their domestication and the ways to proceed further have also been discussed.

Key words: Domestication, Ornamentals, Wild plants

Recently, there has developed a wide interest on the part of many people to grow plants as hobby, or decoration and livability in homes are under priority for cultivation as well as decoration. In due course of time, many of them got naturalized and some become notorious weeds. When we look back to history, it was only through discovering, utilizing and altering the native biotic resources, the locally adapted distinct human races developed. Hence it has been felt that promoting the inclusion of native wild plants of diverse ornamental uses might pave way for diversification of floriculture in light of following points.

1. Since man is curious and generally likes to find things new, any unusual plants suiting to his merit will soon be popularized.
2. Since native plants are well established in their localities on account of their tolerance to biotic and abiotic stresses, their use may reduce the cost incurred.
3. Many potential native plants are in the danger of extinction due to urbanization, climate change, and invasion of alien flora before being utilized by human beings. Keeping in mind the above points, a preliminary investigation on the wild plants with an ornamental look was made in and around Shimla.

Materials and Methods

Areas lying within the radius of 15 km from the heart of the Shimla city were taken into consideration. The surveyed areas ranged from altitude above mean sea level of 1750m (from southern, northern and western parts) to 2450m (eastern parts) representing typical temperate

climate. Trips were made during different seasons for two consecutive years (March 2003 to 2005). Wild plants which are already popular among gardeners (domestic and foreign) are conifers, *Rhododendron arboreum*, *Hedera helix*, etc; those with other better uses and naturalized exotic flora were not considered for study. Herbarium specimens of appealing plants were made along with the notes on their distribution, flowering time, flower colour, habitat, aggressiveness, their present use, etc. Since both art and science are involved in the selection of plants, hence expert opinion was also made.

Results and Discussion

The chosen plants are listed in respective categories based on their nature and utility in landscape (Table 1 & 2)

Annuals

Their flowers lasted for at least a month. Rainy season herbs (*Impatiens*) in temperate hills were found to be gregarious in nature. These plants can well be accommodated in flowerbeds (*Impatiens*, *Cynoglossum*), rock garden (*Silene*, *Impatiens*), herbaceous border, hanging baskets, pot culture (*Chirita*), etc.

Herbaceous perennials

More number of the selected plants belongs to this category. Extreme cold during winter might have favoured these perennials to survive with subterranean root system. They are hardier than annuals but can be used in more or less similar fashion. Apart from that, some plants had potential as groundcover (*Thymus*, *Ajuga*) and for foliage as well as floral values

Table 1. List of wild plants as annual, herbaceous perennials, climber, shrubs and trees from Shimla

S.No.	Plant species	Flowering season	Flower colour	Remarks
A.	Annuals			
1.	<i>Delphinium denudatum</i> Wall.	April-June	Blue	Bee pasturage, needs moist locality
2.	<i>Silene conoidea</i> L.	April-May	Pink	Very attractive, insect trapper
3.	<i>Impatiens sulcata</i> Wall.	July-Sept.	Pink	Rainy season weed; suit to plant around big trees
4.	<i>I. scabrida</i> DC.	May-Sept.	Yellow	-do-
5.	<i>Senecio nudicaulis</i> Buch.-Ham.	May-June	Yellow	Weedy
6.	<i>Cynoglossum furcatum</i> Wall.	June-Sept.	Pale blue or white	Suited to flower garden
7.	<i>Chirita biflora</i> Don	July-Sept.	Blue	Plant with curious basal leaf and slender stem; needs moist and shade
8.	<i>Aneilema divergens</i> C.B. Clarke	July-Aug.	Red-blue	Rainy season succulent plant
B.	Herbaceous Perennials			
1.	<i>Anemone vitifolia</i> Buch.-Ham	June-Sept	White	Tuber bearing; needs shade
2.	<i>Ranunculus laetus</i> Wall.	May-Sept.	Yellow	Moist and shade loving; in borders
3.	<i>Aquilegia pubiflora</i> Wall.	May-June	Pale Purple	Bee pasturage; shade loving; in borders
4.	<i>Viola pilosa</i> Blume	April-July	Lilac	Semi-shade loving; as edge and bedding plant
5.	<i>V. canescens</i> Wall.	April-Nov.	Lilac	-do-
6.	<i>Geranium wallichianum</i> Sweet.	July-Sept.	Blue-Purple	In window boxes, borders
7.	<i>Valeriana wallichii</i> DC.	March-May	White	Needs semi-shade; in borders; also medicinal
8.	<i>Gerbera lanuginosa</i> Benth.	May-Oct.	Pinkish	Pot and garden plant; wooly in look
9.	<i>Erigeron bellediodes</i> (Buch.-Ham.) Benth.	All the time	White	As edge plant; in borders and rocky walls
10.	<i>Primula denticulatus</i> Sm.	March-April	Dark purple	Window boxes; shade loving
11.	<i>Strobilanthes dathousianus</i> C.B. Clarke	July-Sept.	Dark blue	Weedy; very attractive flower and leaves; mass effect in group planting
12.	<i>Thymus serpyllum</i> L.	May-Oct.	Purple	As ground cover; fragrant aromatic plant
13.	<i>Persicaria capitata</i> (Buch.-Ham.) Gross	March-Nov.	Pink	Potted plant; in hanging baskets
14.	<i>Rumex hastatus</i> D.Don	April-Aug.	Reddish	Weedy; gives mass effect if in groups
15.	<i>Bergenia ciliata</i> (Haw.) Sternb.	March-July	Red	Very hardy; foliage plant; medicinal
16.	<i>Ajuga bracteosa</i> Wall.	April-Oct.	Lilac	Foliage plant; shade loving; as groundcover
17.	<i>Mertensia racemosa</i> Benth.	March-April	White	Very attractive; shade loving
18.	<i>Potentilla nepalensis</i> Hook.	July-Aug.	Dark crimson	Shade loving; in borders
19.	<i>Oxalis latifolia</i> Humb.	July-Sept.	Pink	Notorious weed; in window boxes
C.	Climbers			
1.	<i>Clematis montana</i> Buch.-Ham.	April	White	Climber; in pillars, trellises and arches
2.	<i>Parthenocissus himalayana</i> (Royle) Planchon	April-May	Greenish	Woody climber; for fence or over trees; foliage turns reddish in autumn
3.	<i>Vigna vexillata</i> Sm.	April-June	White	Twiner; potted plant in veranda
4.	<i>Rubus paniculata</i> Sm.	April-June	White	Evergreen; pendulous shoots as screen or curtain; also in fence
5.	<i>Rosa macrophylla</i> Lindl.	April-May	Pink	Shrubby climber; hips attractive
6.	<i>Rosa moschata</i> Mill.	April-June	White	Rambler; very common in fences
7.	<i>Jasminum dispersum</i> Wall.	April	Pink	Climber; flowers fragrant; for trellis, arches; attractive black fruits
8.	<i>Jasminum officinale</i> L.	May-July	White	Evergreen climber; also foliage and loose flower value
9.	<i>Trachelospermum lucidum</i> (D.Don) Scheumann	April-July	White	Fragrant; in trellises; needs partial shade
10.	<i>Cymbalaria muralis</i> P. Gaertn.	March-June	Purple	Creeper; in hanging baskets and as ground cover
D.	Shrubs			
1.	<i>Hypericum oblongifolium</i> Choisy	Feb.-April	Yellow	Choice plant; very attractive and more common
2.	<i>Reinwardtia indica</i> Dumort.	Nov.-May	Yellow	Successive flowering; lean season flower for room decoration
3.	<i>Cotinus coggygia</i> Scop.	April-June	Pale Purple	Grace thread-like floral parts; very attractive
4.	<i>Indigofera heterantha</i> Wall.	May-June	Pink	Under shrub for shrubberies; fodder
5.	<i>Deutzia staminea</i> R. Brown	March-June	White	Prolonged flowering period; fragrant; suited for planting along small roads
6.	<i>Woodfordia floribunda</i> Salisb.	Feb.-April	Bright Red	Medicinal; bee pasturage; dye yielding

Contd.

Table 1. Contd.

S.No.	Plant Species	Flowering season	Flower colour	Remarks
7.	<i>Viburnum cotinifolium</i> Don.	April-May	White	Upright flower stalk; very attractive
8.	<i>Lonicera quinquelocularis</i> Hardw.	April-June	Yellow	Hedge; fragrant; very common
9.	<i>Spermadictyon sauveolens</i> Roxb.	Oct-March	Blue	Offseason flower, fragrant; wide adaptation
10.	<i>Jasminum humile</i> L.	May-Oct.	Yellow	Evergreen; graceful foliage
11.	<i>Buddleia paniculata</i> Wall.	March-April	Pink	Highly fragrant; very pleasant flower colour; also foliage value
12.	<i>Caryopteris wallichiana</i> Schauer	March-April	Dark blue	Big inflorescence
13.	<i>Daphne cannabina</i> Wall.	March-Oct.	White	Evergreen; good foliage; fibre value
E. Trees				
1.	<i>Aesculus indica</i> Colebr.	April-May	Pinkish-White	Avenue plant; fodder; very attractive; fast growing; globular-shaped tree
2.	<i>Acer oblongum</i> Wall.	Feb.-April	-	For specimen planting; attractive red foliage while emerging and senescing; avenue tree
3.	<i>Acer caesium</i> Wall.	March-May	-	-Do-
4.	<i>Albizia julibrissin</i> Durazz.	April-May	Pink	Avenue plant; fine textured leaves
5.	<i>Pyrus cerasoides</i> D.Don	Oct.-Nov.	Pink	Very attractive lean season bloomer; specimen plant
6.	<i>Pyrus pashia</i> Buch.-Ham.	April-May	Whitish	Bee pasturage; pear rootstock; noted red foliage while emerging and senescing
7.	<i>Swida macrophylla</i> Wall. (Sojak)	April-June	Greenish Yellow	Very attractive; for specimen planting
8.	<i>Wendlandia exserta</i> DC.	May-June	White	Very attractive
9.	<i>Lyonia ovalifolia</i> (Wall.) Drude	April-May	White	Evergreen
10.	<i>Populus ciliata</i> Wall.	Feb.-April	Greenish	Foliage plant; new flush with catkin very attractive; windbreak; suited for marshy lands.

Table 2. List of wild plants as hedge, bulbous and foliage plant from Shimla

S.No.	Plant Species	Remarks
A. Hedge Plants		
1.	<i>Prinsepia utilis</i> Royle	Armed; fruits blackish and showy; seed oil edible
2.	<i>Berberis lycium</i> Royle	Armed; specimen bush; pale yellow flowers; evergreen; foliage and bluish fruits during autumn very attractive
3.	<i>B. aristata</i> DC.	-Do-
4.	<i>Spiraea canescens</i> Don.	Branches arching; flowers white during May-June
5.	<i>S. bella</i> Sims.	Pink flowers during April-July
6.	<i>Pyracantha crenulata</i> (D. Don) M. Roemer	Armed; White flower; flower during April-May; showy fruit
7.	<i>Cotoneaster microphylla</i> Wall.	Bonsai; edge plant; flowers white with persistent fruits
8.	<i>Rubus ellipticus</i> Sm.	Evergreen; armed; fruits laden plants; very attractive
9.	<i>Elaeagnus umbellata</i> Thunb.	Topiary; very attractive pendulous flowers; during April-May
10.	<i>Myrsine africana</i> L.	Topiary; as edge and under-planting; graceful leaves as cut green
11.	<i>Euonymus</i> spp.	Topiary; foliage plant; fruits attractive; dark green leaves
B. Foliage Plants		
1.	<i>Fragaria vesca</i> L.	April-June; flowers also attractive; also as groundcover
2.	<i>R. purpurea</i> Sm.	-Do-
3.	<i>Hedychium acuminatum</i> Wall.	Medicinal; creamy white flowers during rainy season
4.	<i>Ophiopogon intermedius</i> Don	Foliage value; Dark green leaves; in window boxes, hanging baskets, conservatory; as groundcover
5.	<i>Iris nepalensis</i> Don.	Lilac flowers during April-June; very attractive; shade loving
6.	<i>Arisaema jacquemontii</i> Bl.	Green striped plant; inflorescence very attractive; shade loving

(*Strobilanthes*, *Bergeia*). Most of these plants bloomed over considerable period. They are easy to grow and can be propagated either through seeds or vegetative propagation.

Climbers

This group includes those plants, which climb, trail, creep, twine, ramble, straggle, etc. Trailers and creepers (*Cymbalaria*) can find use in hanging baskets whereas

climbers (*Jasminum*, *Trachelospermum*) in clothing trellises, arches for shade in garden. Ramblers and stragglers (*Rosa*) can best be fitted as screens, boundaries as fence, and for covering bare tree trunks. In this perusal, species of *Rosa*, *Jasminum* and *Trachelospermum* were noted for their fragrance.

Shrubs

There are excellent plants potential as cut flowers (*Reinwardtia*, *Viburnum* and *Buddleia*) while many others had both graceful foliage and flowers. These shrubs can be suited for boundaries, backgrounds and also for specimen planting. A few species flowering during lean season (*Spermadictyon* and *Reinwardtia*) i.e. winter needed a mention since most of the others remain dormant at that time in Shimla.

Trees

There were only a few trees worth to mention as their merit to give colourful landscape. Apart from their multiple uses, many had the merit of attractive foliage (*Swida*, *Acer*, *Albizzia*, *Lyonia*, *Populus*). They can be planted along roadside as avenue plant (*Aesculus*, *Albizzia*) and also as accent plant (*Aesculus*) in garden. They can require comparatively less care than the annual and shrubs. It is special to mention about *Pyrus cerasoides* D. Don, which flowered during the lean season (October to November) while all other deciduous trees had started shedding their leaves. *Acer oblongum* Well. and *Pyrus pashia* Buch.-Ham. were noticed for their attractive red coloured emerging as well as senescing leaves.

Hedges

Many plants under this group were under-shrubs with arm. Some were amenable for topiary (*Elaeagnus*, *Myrsine*, *Euonymus* and *Cotoneaster*) due to their small, densely packed leaves with good rejuvenation capacity after shearing. Some had attractive flowers (*Berberis*, *Elaeagnus*) and/or fruits (*Berberis*, *Prinsepia*), which are showy. Fine textured leaves of *Myrsine* and *Euonymus* can have potential as cut green.

Foliage plants

This group of plants are quite tolerant to low light intensity hence can be accommodated indoors. The plants short-listed are *Fragaria vesca* L., *Begonia amoena* Wall., *B. picta* Sm., *Anthriscus nemorosa* Spreng and *Artemisia vulgaris* L. They were noted for pretty graceful foliage and some were borne with nice-looking flowers. These can well be exploited in rock garden, pots, interior

decoration, and sometimes in flower arrangements (*Artemisia*).

Bulbous plants

Horticulturally, a simple stemmed plant arising from bulbs, corns, tubers or thickened rhizomes is termed as bulbous plant. Usually, the aerial stem disappears during autumn and reappears at the time of melting of snow. They can be suited for mass planting and for pots. They are quick in growth with showy bloom, hence of unceasing favourites with gardeners.

Plants for dry flower arrangements

The beautiful flowers, grasses, sedges, flower-skeletons, seeds, ferns, foliages, sedges, nuts, fruits, pods etc. can be dried, preserved and used in more eco-friendly decoration and in various flower arrangements. It also offers ample employment opportunity. Attractive inflorescence of species belonging to genera of *Bromus*, *Poa*, *Agrostis*, *Avena*, *Alopecurus*, *Erianthus*, and *Polypogon* can be used for this purpose. In this way, many weedy grasses can effectively be utilized. Apart from them, culms and leaves of *Phragmites* sp., unopened inflorescence of *Gnaphalium* and *Anaphalis* spp. can also be used as everlasting. The attractive leaves of *Adiantum*, *Polypodium*, *Pteris*, and *Selaginella* spp. can be dried (after glycerine treatment) and used for various flower arrangements (Singh, 2003).

Plants for rock garden

Since the area under investigation is in Himalaya, there are ample plants of saxicolous nature suiting to this type of garden: Plants belonging to the genera such as *Bergenia*, *Sedum*, *Androsace*, *Anemone*, *Aquilegia*, *Corydalis*, *Cotoneaster*, *Iris*, *Potentilla*, *Primula*, *Saxifraga*, and *Thymus* may be exploited for this purpose.

Miscellaneous

Dryness and cold winter leave only terrestrial orchids in Shimla. Only two species viz. *Habenaria edgeworthii* Hook.f. (yellow-flowered) and *Satyrium nepalense* Don (pink-flowered) were attractive and they appeared during rainy season. A weed, *Polygonum aviculare* L. Can be used as bedding plant in carpet beds because of its attractive reddish green foliage with creeping nature while *Poa annua* L., *Festuca myuros* L. and *Lolium* spp. can be used as lawn grasses on account of their excellent sod forming nature with wider adaptation and attractiveness. Ferns and their allies found in Shimla belonging to the genera *Selaginella*, *Adiantum*, *Lygodium*, *Davallia*,

Polypodium and *Equisetum* can be introduced into fernery. Many seemed to be suitable for indoor culture and in hanging baskets. So far mentioned wild ornamentals are either weeds in cultivated premises or the plants found wild in feral areas. Like cultivated plants, these untamed plants are also evolved under the control of natural selection but without the patronage of planter. Hence, accompanying of some undesirable traits with these plants is always expected, which needs to be addressed. Apart from some specific constraints in each utilitarian group, most of the general constraints include comparatively small size of flower and seed, violent seed shattering, erratic seed germination, variable growth and development of plants which is not desirable for commercial cultivation and many of them show reluctance to changed ecological niche. It is more pronounced in temperate wild plants than their tropical counter partners. This calls for the need of domestication. Domestication in native climate is much easier since soil-climate complex remains more or less same. According to Kupzow (1980), weeds of convergent adaptation (those imitating crop plants) and anthrophilous wild plants (plants liking human interferences) are easy to domesticate. Diligent observation is therefore needed to find the behaviour of these plants. It is once we start cultivating these plants, wider diffusion of these plants into cultivated area is possible due to struggle for existence. This will result in genetic changes in the composition of population due to acclimatization hence it offers scope for subsequent for better types of our choice. If plants are more averse and divergent in adaptation, then transmutation through mutagens or genetic transformation may facilitate the above process. During our investigation, we have found considerable morphological variability in *Valeriana wallichii* DC., *Reinwardtia indica* Dumort., *Rubus ellipticus* Sm., *Jasminum humile* L. and *Thymus serpyllum* L. Collection and characterization of this variability can be the first step for domestication process. Influence of altitude-underlined parameters with respect to time of flowering was also noticed in many plants. Usually, 20-30 days difference in flowering was noticed in plants occurring among the lower limit (very early) and other areas (late) such as *Aesculus indica* Colebr., *Berberis lycium* Royle, *Rosa moschatta* Lindl. and *Pyrus pashia* Buch.- Ham.. This observable fact can well be exploited by setting out production centers in different elevations so that staggered harvest of flowers can be possible for those wild ornamentals having wide range of adaptation. Enormous plasticity of high altitude plants such as

Bergenia ciliata (Haw.) Sternb. and *Valeriana wallichii* DC. At elevation as low as 1300m, may help in promoting these plants in untraditional areas too. For cut flower purpose, long flower stalk with large number of big-sized flowers lasting for at least a week is desired. In this context, an initial try can be made on the species like *Delphinium denudatum* Wall., *Rosa moschata* Mill., *Spermadictyon suaveoloens* Roxb., *Reinwardtia indica* Dumort., *Caryopteris wallichiana* Schauer and *Buddleia paniculata* Wall., since they appear to suit the requirements. Simultaneously, experiments on increasing their stalk length, vase life and for betterment of packing can be conducted. In case of foliage plants mutation studies can yield best results. These selected plants can be tried in temperate hills of India keeping in view the season. In this regard, those plants flowering more or less throughout the year (*Thymus serpyllum* L.), *Erigeron belledioides* (Buch.-Ham.) Benth, during lean season i.e. late autumn (*Prunus cerasoides* D. Don) and winter (*Reinwardtia*, *Spermadictyon*) and those with considerably long period of flowering can be given more attention. Promotion is very easy of those plants having multiple uses particularly in homestead garden. Now it is too early to recommend propagation methods and cultivation practices since it needs further experiments. Careful examination of the table 1 and 2 reveals that almost all kinds of flowers with different hues over different periods and situation occur in this hilly resort. So in our opinion, there is no dearth of wild flowers from this area for beautification. At the same time, it is awesome to note that many beautiful plants mentioned in the famous 'Flora Simlensis' of Collet (1902) are now difficult to trace out. For instance, *Aconitum heterophyllum* Wall. and *Lilium polyphyllum* D. Don are a few to mention. This ultimately calls for the need for conservation. National Bureau of Plant Genetic Resource Regional Station. Shimla has just made an initiative in this regard. Establishing a botanical garden comprising these wild ornamentals may gratify this reality. These wild plants also reduce the maintenance cost involved there in compared to exotic flora.

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Genetic Resources of Aonla (*Emblica officinalis* Gaertn.)

Arun K Shukla*, DK Samadia, Anil K Shukla and DG Dhandar

Central Institute for Arid Horticulture, Beechwal, Bikaner-334 006 (Rajasthan)

Aonla tree has gained great socio-economic impact in large part of the country. It has significant contribution to improvement of economic status of farming communities through commercial orcharding, nursery production and processing of herbal respect of fruit size, maturity period and yield per plant. Due to predominance of seedling propagation India holds rich genetic diversity in cultivated and their wild relatives of aonla. Genetic erosion status of these resources is constantly high due to severe deforestation, natural calamities and adoption of a few popular cultivars in the selected pockets. However, enormous variability in aonla still remains unexploited and awaits proper attention on exploration, collection and maintenance to conserve genetic diversity available in the nature. Besides cultivated species of *Emblica* (*Phyllanthus*), some other available species can be utilized in aonla breeding programme to infuse hardiness into the offspring for adverse habitat. This paper discusses the diversity region, extent of variability with respect to quality, fruit character, germplasm holdings, evaluation and selection of genotypes, etc.

Key words: Aonla, Diversity, Genetic resources, Germplasm

Exploitation of the potential of under utilized fruit crops will not only benefit the countries in which they are produced, but also cater to the increasing demand for exotic products in the developed world. Thus resolving the problems associated with these crops is a global challenge that needs to be addressed collectively. Aonla has been regarded as a sacred tree in India. The tree is worshipped as mother earth and is believed to nurture humankind because the fruits are very nourishing. It is also known as amritphal and mainly recognized due to its high nutritive, medicinal and therapeutic properties. It contains high amount of vitamin-C (500-1500mg/100g), it is also rich in pectin, iron, calcium and phosphorus. Dried fruits of aonla can be is used in curing hemorrhage, diarrhea, chronic dysentery, diabetes, jaundice, dyspepsia, cough etc. Recently, aonla has gained more popularity in arid and semi-arid region of the country because of its hardy nature, prolific bearing capacity and ability to grow under various adversities as a remunerative crop (Shukla *et al.*, 2002). It may be an important fruit in future due to its high productivity, suitability in wasteland particularly salt affected soil and sandy soil of arid ecosystem. Aonla is the main ingredient of *Chyavanprash* and *Triphala* powder, which is used for curing different abnormalities. The fruit contains a chemical substance galic acid and leucoanthocyanin, which have antioxidant property.

However, production of aonla is besieged with certain problem viz. Variable sex ratio, fruit dropping, prolonged fruit bud dormancy, shy and alternate bearing, fruit necrosis, ring rust and fruit rot diseases, post harvest losses, poor quality of value added products and lack of marketing

Composition

S.No.	Components	Quantity
1	Vitamin-C (mg/100g)	600-1100
2	Vitamin-A(I.U.)	10-100
3	TSS (%)	10-25
4	Acidity (%)	1.5-2.5
5	Total sugar (%)	3.5-5.5
6	Reducing sugar (%)	2.0-4.0
7	Pectin (%)	2.5-3.5
8	Phosphorus (Fresh weight, mg)	1.5-2.5
9	Phosphorus (Dry weight, mg)	7.5-15.0
10	Sulphur (Fresh weight, mg)	7.0-20.0
11	Sulphur (Dry weight, mg)	20.0-80.0
12	Iron (Fresh weight, mg)	10.0-20.0
13	Iron (Dry weight, mg)	50.0-100
14	Total minerals (Fresh weight, %)	0.35-0.70
15	Phenols (Dry weight, %)	2.0-4.0
16	Pulp (%)	80-95
17	Fibre (%)	0.8-2.5
18	Seed (%)	3.5-8.0
19	Dry matter (%)	12.0-20.0
20	Juice (%)	45.0-78.0

facilities. Keeping in view its vast potential and significance to export trade there is need to make efforts for efficient management of aonla post harvest technology for improving the productivity and utilization of quality produce of aonla.

Taxonomy

Aonla (*Emblica officinalis* Gaertn.), which is also known as Indian gooseberry, myrobalan and emblic, belongs to the family Euphorbiaceae which comprises about 350 (Hooker, 1973) to 500 species (Bailey, 1917) mostly shrub, few herb or tree. It bears two types of shoot. On the basis of growth characteristics, these have been categorized as long or indeterminate (Bajpai, 1965). The indeterminate

shoots are longer and continue to put forth new growth in the season. The determinate shoot appears on the nodes of indeterminate shoots and their numbers at each node may vary from 3-5 in different cultivars. These determinate shoots bear small sized leaves (9-14 x 2-4 mm), which are of simple type. Flowering in aonla takes place during March-April under hot arid conditions and in the month of February in Uttar Pradesh on newly emerged determinate shoots. However, there are two prominent cropping season in South India i.e. July-August and April-May (Naik, 1963). The fertilized ovary of aonla is unlike those of other fruit plants, which remains dormant for 3.5 month and resume growth following division in endosperm and zygote nuclei in the month of August. The fruits mature some times in December under hot arid ecosystem of Rajasthan. Other related species *Phyllanthus acidus* commonly known as star gooseberry is grown for ornamental purposes. In arid and semi arid conditions aonla is observed to be deciduous in nature due to abscission of determinate shoots during January -February. Generally, it bears two types of shoot i.e. determinate and indeterminate shoot. The indeterminate shoots are longer and continue to put new growth in the season while flowers are borne in the axil of the leaves on determinate shoot as axillary cymules. In North India, senescence /leaf shedding of aonla plants begin in the month of February and complete shedding of determinate shoots takes place in the end of February to mid of March. The new shoots emerged out during first week of April (Bajpai, 1965, Ram, 1971 and Shukla *et al.*, 2004a). The flowering occurs twice in a year, February- March and June-July (Naik, 1963). In aonla male flower appears first in the axil of leaves at the distal end of same shoot. The percentage of female flower varies from 1.12 to 8.33 depending upon varieties. Aonla is highly cross pollinated crop due to its monoecious nature and pollination takes place through wind, honey bees and gravity (Reddy and Janki Bai, 1979). The common visiting hours of honeybees is late evening and morning (Bajpai, 1957). Fruit setting can be increased up to 18-28 per cent by hand pollination. However, Pathak and Pathak (1993) did not notice any fruit set for a number of years in some isolated Banarasi aonla plant even after profuse flowering. It indicates the presence of self-incompatibility in this cultivar. A gene controlled natural incompatibility system is held responsible for unfruitfulness in some aonla cultivars. Information related to narrow and broad based heritability of desirable traits is still lacking. Preliminary observations indicated that yield

attributing traits are poligenically inherited as crosses between large and small-fruited types failed to produce any set segregation pattern in the progenies with respect to fruit size and related attributes.

Genetic resources

Aonla is a hardy fruit plant, which can be successfully grown under various agro-edaphic situations. It is said to be indigenous to tropical south-eastern Asia particularly in central and southern India (Firminger, 1947). It is also reported to be the native of India, Sri Lanka, Malaysia and China. Aonla thrives well throughout Tropical India and is met with wild or cultivated species in the region extending from the base of Himalaya to Sri Lanka and from Malacca to south China. In India, aonla is widely grown in Uttar Pradesh, Gujarat, Rajasthan, Madhya Pradesh Tamil Nadu etc. The seedling aonla plants are commonly observed in Vindhyan hills, Northern hills region (Garo, Khasi and Jaintia hills) and also in North-western Himalayan region up to the elevation of 1350 m above msl. Besides, the potential areas for aonla diversity is Andhra Pradesh (Vizag), Gujarat (Anand, Nadiad), Madhya Pradesh (Panna), Maharashtra (Ajanta, Akola, Bhandara, Buldana, Chandrapur, Jalgaon, Kolhapur, Ramtek, Satara and Yotmal), Tamil Nadu (Annamalai, Azhakiapandiapuram, Khrayamtels, Krishnagiri, Nilgiri hills, Panpozhi, Salem and Siruwani hills), Uttaranchal (Kumaon hills), Uttar Pradesh (Azamgarh, Bareilly, Pratapgarh, Raebareli, Sultanpur and Varanasi). In aonla variability exists in seedling population in respect of fruit size, maturity period and yield per plant. In fact seed germination is not a problem therefore, great genetic variability is being found for desirable economic traits in aonla growing areas of the country. Besides cultivated species of *Emblia* (*Phyllanthus*), some other available species can be utilized in aonla breeding programme to infuse hardiness into the offspring for adverse habitat. Recently, an exploration was conducted in parts of hill ecosystem of Himachal Pradesh, where it was found that there is ample scope for selection of frost tolerant/resistant types, although the fruit size was smaller but plants are more hardy than existing commercial varieties (Shukla and Dhandar, 2003). Further, Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh, Jharkhand and NEH region are hunting ground for aonla variability.

Genetic variability regions

Aonla is found in dry deciduous forest of India except in extreme North-west ascending to 1450m in Himalayas.

Centres	No. of collections
Abohar	—
Anantpur	15
Arrupukottai	15
Bawal	06
Bikaner	—
Bangalore	—
Faizabad	22
Jodhpur	03
Jobner	06
Mundra	—
Rahuri	08
SK Nagar	12

* Source: Status of genetic resources of aonla at AICRP centers (Saroj and Awasthi, 2004)

State/Region	Diversity Areas
Andhra Pradesh	Vizag, Anantapur
Gujarat	Anand, Nadiad, Surendranagar
Rajasthan	Ajmer, Jaipur, Kota, Churu, Hanumangarh, Alwar, Jaisalmer
Maharashtra	Akola, Bhandara, Buldana, Chandrapur, Jalgaon, Kolhapur
Tamil Nadu	Salem, Dindigul, Tuticorin
Uttar Pradesh	Vindhyan hills, Bundelkhand, Allahabad, Mirzapur, Sonbhadra, Mathura, Agra, Etawah, Mainpuri
Madhya Pradesh	Bhopal, Gwalior, Shivpuri, Indore, Sheopur, Betul, Hoshangabad, Balaghat, Satna, Sidhi, Panna
North-western Himalaya	Jammu & Kashmir, Himachal Pradesh, Uttaranchal up to 1500m above sea level
North-eastern Himalaya	Assam, Meghalaya, Manipur, Tripura, Khasi hills, Mizoram

Conservation and evaluation of elite genotypes at different centres

Organizations	Accession No.	References
Dryland Agril. Research Station, Anantapur, A.P.	12	Pareek, 1998
Agril. Research Station, Arrupukottai	05	Pareek, 1998
Dryland Agril. Research Station, S.K. Nagar, Gujarat	12	Pareek, 1998
NDUAT, Faizabad	21	Pareek, 1998
GBPUAT, Pantnagar	10	Ram, 1993
CIAH, Bikaner	43	Shukla <i>et al.</i> , 2004
NBPGR, New Delhi	05	Anonymous, 1999
CISH, Lucknow	12	Pathak <i>et al.</i> , 2003
MPKV, Rahuri	06	Karle, 2000

It is also found in Sri Lanka, USA, Cuba, Iran, Pakistan, Iraq, China, Malaysia, Thailand, Philippines, Vietnam, Trinidad, Japan, etc. This crop has extensive adaptability to grow under diverse climatic conditions ranging from non-tropical plains to humid sub tropical mid elevation hills. The forests have been traditional source of aonla for medicinal uses estimated to be 41000 tonnes. Out

of this about 35000 tonnes of aonla is collected from the forests of Madhya Pradesh. Increasing demand from industry, especially for Ayurvedic formulation and appreciation of nutraceutical and medicinal properties for its house hold consumption has resulted in growing of this tree as cultivated crop. Initially, it was grown as seedling tree having large variability coupled with long gestation period. Higher economic return from the crop, coupled with increasing demand had led to commercialization of aonla across the country. Aonla has great potential for its export to meet the growing demand of health conscious population. Further, Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh, Jharkhand, and NEH region are hunting ground for aonla variability. Besides, hill and mountain ecosystem viz., Vindhyan hills, Himachal Pradesh are areas where tremendous variability was found.

Range of variability in plant characters

Aonla being highly cross pollinated crop seedling plants depict heterozygosity in morphological and physiological traits of tree.

A. Plant phenology

Plant height	5-10 m
Canopy spread	4-6 x 3-5 m
Girth	40-100 cm
Lengths of determinate shoot	10-25 cm
Size of leaf	2-4 cm
No. of fruit/shoot	5-15
No. of viable shoots/branch	20-40
No. of female flower/shoot	5-15
Fruit yield (kg/tree)	50-150
Period of fruit availability	October-January
Flowering period	February-April

B. Fruit characters

Fruit colour	Apricot yellow-Reddish yellow
Fruit weight	26-40 g
Fruit size	2.27-4.10 cm
Pulp weight	24-38 g
Pulp content	89-95%
Pulp thickness	1.5-2.10 cm
Stone weight	1.12-2.27 g
Stone length	1.1-2.1 cm
Stone width	1-1.7 cm
Stone content	5-13%
Seed number	4-8
Seed content	0.015-0.056%
Number of segments	5-8
Seed weight	0.2-0.5 g

C. Variability for quality

Vitamin-C	568-950 mg/100g
Dry matter	12-25%
TSS	10-24%
Acidity	1.1-2.23%

Ideotypes of aonla

Plant traits	Dwarf, regular in bearing, precocity in bearing, wider adaptability, early and late maturity
Fruit yield	High
Fruit quality	Surface colour, high vitamin-C
Seedlessness	Small-sized
Resistance to physiological disorders	Disorders like necrosis and misshapen fruits
Fruit weight	>38 g
Fruit length	>4 cm
Fruit width	>4 cm
Fruit shape	Oval to oblong
Acidity	3.5<
Vitamin-C	>550 mg

Utilization of Genetic Resources

Most of the plantations have been raised from seed. Therefore, these exist a great variability. Some named cultivars like Banarasi, Francis (Hanthijhool), Chakaiya and Bansi Red are known to be the natural selections, which got acclimate in specific agro climate zones and they possessed some merits and demerits. For instance, Banarasi is early maturing but shy bearer (less number of female flower/branch let) and prone to heavy dropping of fruits with poor shelf life. Francis suffers from severe incidence of fruit necrosis and Chakaiya fruits are fibrous, small in size with tendency to bear heavy crop in alternate years. Besides these natural selections new selections have been identified at NDUAT, Faizabad and are released for commercial cultivation. These are Kanchan-NA4 and Amrit-NA6 (selection from Chakaiya), Krishna and Neelam-NA7 (selection from Banarasi) and Balwant or Agra Bold-NA10 (selection from Banarasi). Similarly in Gujarat, Anand1, Anand 2, Anand 3 from seedling population available in the area are new promising types. In the early the years there was no improved cultivars of aonla. Some popular types were named after locality

of their occurrence, plant type and fruit colour, Banarasi, Chakaiya, Hathijhool, Green tinged, Red tinged, White streaked, and Bansi red, being grown among them.

Germplasm survey, collection and evaluation work on aonla was initiated at the Narendra Dev University of Agricultural and Technology, Faizabad during 1982-83. Nineteen germplasm including 10 in fruiting stage are being maintained at this university. Considerable variability in fruit shape (round, flattened, round and triangular); length (3.91-2.90cm); width (4.50-3.50cm); fruit weight (50.55-26.91g); number of segments (6); fruit colour (whitish-green to apricot-yellow, yellowish green, light green with pink tinge, pink); seed size small to large; flesh colour whitish green to pink; fibre more to less; TSS (8-14%); acidity (1.9-2.5) and ascorbic acid 422-600mg/100g pulp have been observed with available genotypes. Diversity in vegetative growth (upright, spreading, drooping; flowering (February end to first week of April); sex ratio (1: 28- 1:355); fruit maturity and productivity have also been observed with these genotypes.

Some Promising Selections

Banarasi : It is developed through seedling selection from Varanasi district of U.P. It is shy bearing in nature due to less number of female flowers and presence of self incompatibility. It is rich in vitamin-c. It is an early maturing variety and mild susceptible to necrosis.

Francis : It is seedling selection popularly known as Hathijhool. The branches are dropping habit, moderate bearer, and greenish yellow fruit, nearly fibreless and highly susceptible to necrosis.

Chakaiya : It is also seedling selection having spreading growth habit. It contains fibrous fruits with six segments. It is late maturing variety and free from necrosis.

Krishna : This is chance seedling of Banarasi from Pratapgarh. It is early maturing var.shy bearing habit, pinkish green flesh and less fibrous.

Important merits and demerits of aonla genotypes

Variety	Breeding method	Merits	Demerita
Banarasi	Seedling selection	Bold size, upright growth, high vitamin-C	Less number of female flower, self-incompatibility, shy bearer
Francis	Seedling selection	Large fruit size	Susceptible to necrosis, drooping growth habit
Chakaiya	Seedling selection	Profuse fruiting	More fibre content
Krishna (NA-4)	From Banarasi	large fruit	Shy bearer
Kanchan (NA-5)	From Chakaiya	Regular bearer, preferred by industries	Small size fruits
NA-6	From Chakaiya	Less fibre content	Fruit cracking/misshapen fruit
NA-7	From Francis	Free from necrosis, prolific bearer	Limb breakage
NA-10	Banarasi	Bold fruit	Moderately susceptible to necrosis

Kanchan : It is believed to be a chance seedling of chakaiya. It is spreading growth habit and bears profusely; fruit is yellowish in colour and suitable for pickle preparation.

NA-6 : It is chance seedling of Chakaiya. It is semi-spreading growth habit, light green colour of fruit, good keeping quality, late maturing, moderate bearer and free from necrosis.

NA-7 : It is seedling selection from open pollinated strain of Francis. It is precocious and prolific bearer, mid season, free from necrosis and suitable for preserve making.

NA-8 : It is chance seedling of Chakaiya. It is upright growth habit, late maturing, moderate bearer, susceptible to necrosis and good keeping quality.

NA-9 : It is seedling selection from open pollination strain of Banarasi. It is semi spreading growth habit, moderate keeper, early, shy bearer and susceptible to necrosis.

NA-10 : It is chance seedling developed from Banarasi locally known as Agra Bold. It is semi spreading growth habit, yellowish green with pink tinge, highly astringent, good keeping quality, early, moderate bearer and moderately susceptible to necrosis.

Balwant : It is developed through selection from Banarasi at RBS College, Agra, UP. It is prolific bearer, semi spreading growth habit, moderate bearer and good keeping quality.

Anand- 1 : It is developed at GAU, Anand. It is moderate bearer.

Anand- 2 : It is also developed from GAU, Anand. It is prolific bearer, fair keeping quality.

Laxmi-52 : It is developed from CISH, Lucknow.

Genetic improvement

Selection

Most of the Indian varieties are developed through selection. Major research work in this direction is being done at NDUAT Faizabad, GAU, SK Nagar, RBS College, Agra etc. Recently, some cluster bearing and coloured genotypes has been identified through exploration in Rajasthan, which will be further evaluated at national repository of aonla at CIAH, Bikaner. While selecting new ideotypes some important plant characteristics are kept in mind i.e., plant height, vigour, growth habit, precocity, fruiting intensity and fruit size, etc.

Hybridization

In order to get combination of highly desirable traits

in one cultivar a systematic crossing programme is essential. There is an apparent need to create some genetic combination by fusion of segregating gametes of the seedling population. While sexual progenies may have comparatively low mean performance related to the parental clone, the range in the performance of the progeny can be greater with some individual exceeding the performance of the best parent. Such transgressive segregants having both good genes and better combination of genes can be selected and propagated asexually. These superior individual can become variety or may be used as superior parental clones in future breeding programme. Occurrence of xenia effect between Chakaiya x Krishna, Banarasi x NA-9, Francis x NA-7, Kanchan x NA-6 and NA-6 x NA-9 for fruit size and weight were reported from the crosses. (Srivastava and Pathak 1993).

Mutation

In India, research work related to application of mutation in aonla is almost negligible but there is greater prospect to develop coloured varieties through induced mutation and selection from bud sport.

Polyploidy

Exact ploidy level is not known in aonla but it is realised that aonla is characterized by polyploidy behaviour in composition of chromosome. The structural and numerical changes in chromosome can be made through application of colchicine, which is found to be useful for getting small seeded fruit or seedlessness. Keeping in view the usefulness of polyploidy breeding, these principles may be applied in aonla to obtain desirable economic attributes.

Major problems in aonla

- Since, aonla is highly heterozygous plant, therefore, large size of population is required for selection
- It has long generation cycle i.e., 2-8 years, depending upon species and varieties
- Lack of recombination
- Long juvenile phase prohibiting early assessment of strain
- Presence of self-incompatibility
- Frost susceptibility
- Lack of knowledge on inheritance pattern

Strategies

- Varietal development for wider geographic adaptability.
- Varieties suitable for export and based on market demand.

- Resistant to frost. Rust disease and drought.
- Development of varieties with less fiber content and good pollinating variety.
- Varieties with high sex ratio with more number of female flowers.

Future line of work

- Development of varieties with high percentage of female flowers.
- It is desirable to breed colored variety as its demand in the trade market would be more in comparison to traditional varieties.
- Exploitation of heterosis (hybrid vigour).
- To evolve variety with very small stone size.
- Development of variety suitable for export purpose.
- Development of transgenic aonla through biotechnological tools.
- Breeding for resistant to frost, biotic and abiotic stresses.

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Utility of P450-Based-Analogue (PBAs) Markers for Diversity Analysis of Linseed (*Linum usitatissimum* L.) Cultivars

MK Rana, Munjal D Vyas, Sonika Singh and KV Bhat

National Research Centre on DNA Fingerprinting, National Bureau of Plant Genetic Resources, New Delhi-110 012

Molecular marker techniques to unravel genome-wide variation scattered in the functional regions are becoming available with the advancements in DNA research. These could be of greater utility for assessing genetic diversity at the molecular level than the neutral marker techniques. Mammalian cytochrome P450 analogues (PBAs) in crop plants are said to be ideal tools in this direction. The utility of these was tested for assessing intra-specific diversity in twenty-one linseed cultivars. The results with fifteen primer-combinations suggested that of the total 136 markers that were generated only 25% were found to be polymorphic. The level of polymorphism in linseed cultivars was quite low, although it was possible to discriminate all the cultivars using combined profiles. The grouping of the cultivars using these markers, however, could be related to the known pedigrees.

Key words: *Linum usitatissimum* L., Cytochrome P450, Genetic diversity, Linseed, DNA markers

Molecular markers, particularly DNA based, have been proving to be very useful in many ways, directly or indirectly, for enhancing the genetic potential of crop plants for improved end-products. Many such markers including restriction fragment length polymorphisms (RFLPs), random amplified polymorphic DNA (RAPD), amplified fragment length polymorphisms (AFLPs), simple sequence repeats (SSRs) etc. (Powell *et al.*, 1996; Karp *et al.*, 1997) are now available in the kitty of plant breeders and molecular biologists. Using these markers only genetically neutral regions have been assessed so far in different crop plants for genetic diversity studies. Moreover genetic diversity represented by these markers is not necessarily representative of the whole genome. For appropriate and useful diversity, genome-wide functional regions of the genomes need to be assayed.

Cytochrome P450 are the enzymes involved in polysaccharide biosynthesis, disease related genes, transcription factors, protein kinases and phosphatases, to name a few. A large number of gene families have been observed for these cytochrome P450 in human and other animals. Analogues of these mammalian cytochrome P450s, are commonly observed in angiosperms (Watnabe *et al.*, 2000; Suzuki *et al.*, 2001). Primers corresponding to the functional regions of these human cytochrome P450 can be designed to generate markers and using such markers, it has been observed that these sequences are distributed through out the *Arabidopsis thaliana* genome. Such markers have been termed as P450-based-analogues (PBAs) and have been demonstrated as effective genetic markers for genetic diversity studies reflecting both functional and genome-wide regions (Yamanaka

et al., 2003). In the present study we report the utility of these PBAs for assessing intra-specific diversity in linseed (*Linum usitatissimum* L.).

Materials and Methods

Plant material and DNA extraction

Twenty-one linseed (*Linum usitatissimum* L.) cultivars (Table 1) released for different agro-climatic regions of the country over different years were included in this study. DNA from at least ten plants of each of the cultivar was extracted following CTAB method (Saghai-Maroo *et al.*, 1984) with minor changes. The extracted DNA was purified for various contaminants using phenol and was further quantified fluorimetrically. The DNA samples were diluted with Tris: EDTA (1 : 1) buffer to give a final concentration of 10 ng⁻¹. Bulk DNA sample for each cultivar was prepared by pooling equal amount of DNA from each of the plant-wise extracted DNA. These working stocks were kept at 4°C in the refrigerator for regular use whereas the original stocks were stored at -20°C.

PCR amplification and gel analysis

PCR amplification was carried out in 25 µl of total reaction volume containing 1 X PCR buffer (10mM Tris-HCl, pH 9.0; 1.5 mM MgCl₂; 50mM KCl; and 0.01% gelatin), 40 ng of genomic DNA, 2.5 mM MgCl₂ (M/s Sigma Aldrich), 1 unit of Taq DNA polymerase (M/s Bangalore Genei Pvt. Ltd.), 0.5µM each of forward and reverse primers (M/s Sigma Aldrich) and 0.2mM of dNTP mix (M/S. Bangalore Genei Pvt. Ltd.). PCR amplification for 32 cycles was programmed as: 1 min. at 94°C,

Table1. Linseed cultivars included in the study

S.No.	Cultivar Name	National Identity	Pedigree
1	Padmini	IC-426932	Not available
2	Parvati	IC-305053	Not available
3	Rashmi	IC-426929	Not available
4	Shekhar	IC-305055	Not available
5	Sheela	IC-426928	Not available
6	Shubhra	IC-113108	Mukta x K-2
7	Sweta	IC-113107	Mukta x T-1206
8	T-397	IC-113110	T-491 x T-1193
9	NL-97	IC-305109	Not available
10	Neelum	IC-113109	T-1 x NP (RR) 9
11	Meera	IC-427794	Developed through mutation
12	LC-185	IC-113156	NP (RR) 37 x Kangra Local
13	LC-54	IC-113155	K-2 x Kangra Local
14	Laxmi-27	IC-113105	Neelum/kp1/NP(RR)9/Neelum/R1/Neelum/ Afg.8
15	KL-210	IC-420772	Not available
16	KL-31	IC-426935	New River x LC 216
17	KL-1	IC-426936	IC-216 x IC-185
18	Kiran	IC-426925	(R-1 x Afg.8) x R-1
19	Jawahar-552	IC-426926	No. 55 x B-67
20	Gaurav	IC-113111	Sel.-3 x EC-1552
21	Garima	IC-426930	T-126 x Neelum

2 min. at each annealing temperature and 3 min. at 72°C in a PTC-200 thermal cycler (M/s MJ Research). Annealing temperature for each primer-set was as described by Yamanaka *et al.*, (2003).

A total of fifteen primer combinations which included three forward [CYP1A1F (5'-GCCAAGCTTTCTAACAATGC-3'), CYP2B6F (5'-GACTC TGTCTACTCTGGTT-3'), and CYP2C19F (5'-TCCTTGTGCTCTGTCTCTCA-3')] and five reverse [CYP1A1R (5'-AGGGACATGCTCTGACCATT-3'), CYP2B6R (5'-CGAATACAGAGCTGATGAGT-3'), CYP2C19R (5'-CCATCGATTCTTGGTGTTCT-3'), Heme2B6 (5'-ACCAAGACAAATCCGCTTCCC-3') and Heme2C19 (5'-TCCCACACAAATCCGTTTTCC-3')] were used for PCR amplification (Inui *et al.*, 2000, Kiyokawa *et al.*, 1997). After completion of PCR 2.5 µl loading dye was added to each tube and briefly spun for few seconds for mixing. A 1.5% agarose gel with ethidium bromide (10mg/ ml) was prepared and electrophoresis was carried out at 80 volts for 2 hours. The resolved amplification products were visualized under UV light and photographed with black and white Polaroid film 667.

Data analysis

Jaccard's similarity coefficient values (Jaccard, 1908) for each pair-wise comparison between cultivars were calculated and a similarity coefficient matrix was constructed. This matrix was subjected to unweighted pair-group method for arithmetic averages analysis (UPGMA) to generate a dendrogram using average linkage procedure. Free Tree software was used to construct the dendrogram (Pavelicek *et al.*, 1999). Analysis of molecular variance (AMOVA) was applied on the Euclidean distance matrix between cultivars to partition the total genetic variation (Excoffier *et al.*, 1992). Statistical significance of variances was tested by random permutation, with the number of permutations set at 1000. AMOVA was done using computer software Arlequin (Schneider *et al.*, 2000). Robustness of the clustering pattern was tested using 1000 resamplings using Free Tree software.

Results and Discussion

Two parameters, namely, sample DNA concentration and the concentration of MgCl₂ were needed to be standardized to obtain optimum amplification. The MgCl₂ concentrations that were tried included 3.0 mM, 3.5 mM, 4.0 mM and 4.5 mM, whereas, different DNA sample concentrations were 20 ng, 30 ng, 40 ng and 50 ng. A combination of these two parameters suggested that 40 ng of genomic DNA and 4.0mM of Mg Cl₂ gave optimum amplification and were used for PCR amplification using all the primers tested.

All the 15 primer-combinations could produce successful amplification, however, the number of bands observed with primers CYP1A1F/ CYP1A1R and CYP2B6F/ CYP2B6R was very low (3 bands in each case). One-third of these primer-combinations did not produce any polymorphic amplicons among the linseed cultivars. The maximum level of polymorphism (57.1%) was observed for primer CYP1A1F/ CYP2B6R followed by the primer CYP2C19F/ Heme2B6 (54.5%) (Table 2). The profiling of 21 linseed cultivars using the later (CYP2C19F/ Heme2B6) along with another primer-combination (CYP2C19F/ CYP1A1R) is presented in Figure 1. On the whole, 25% polymorphism was observed using this set of 15 primer-combinations which was quite low as compared to what has been recorded in *Lycopersicon esculentum* (97.8%), *Solanum tuberosum* (94.1%) and *Capsicum annuum* (87.5%) by Yamanaka *et al.* (2003). These workers could get large number of polymorphic bands in a very limited set of accessions within a species. For example, in only six *Lycopersicon esculentum*

Table 2. PBA primers used and extent of polymorphism revealed in linseed (*Linum usitatissimum* L.) cultivars

Sr. No.	Primer Combinations	Total number of bands	Number of polymorphic bands	Per cent polymorphism
1.	CYP1A1F/ CYP1A1R	3	0	0.00
2.	CYP1A1F/ CYP2B6R	7	4	57.1
3.	CYP1A1F/ CYP2C19R	14	5	35.7
4.	CYP1A1F/ Heme2B6	13	2	15.4
5.	CYP1A1F/ Heme2C19	6	0	0.00
6.	CYP2B6F/ CYP1A1R	10	4	40.0
7.	CYP2B6F/ CYP2B6R	3	1	33.3
8.	CYP2B6F/ CYP2C19R	12	0	0.00
9.	CYP2B6F/ Heme2B6	11	5	45.4
10.	CYP2B6F/ Heme2C19	12	2	16.7
11.	CYP2C19F/ CYP1A1R	13	5	38.5
12.	CYP2C19F/ CYP2B6R	5	1	0.20
13.	CYP2C19F/ CYP2C19R	10	0	0.00
14.	CYP2C19F/ Heme2B6	11	5	54.5
15.	CYP2C19F/ Heme2C19	6	0	0.00
		136	34	25

accessions, ten out of fifteen primer-combinations were cent per cent polymorphic. In the same set of 21 linseed cultivars we have observed 34 and 43% polymorphism using 20 RAPD and 15 ISSR primers, respectively (unpublished results). It is discernible from these comparative estimates that PBA markers are significantly less polymorphic than RAPD and ISSR markers in linseed.

Jaccard's similarity estimates among the cultivars using these markers ranged from 0.819 (Garima-Kiran) to 0.975 (KL210-Laxmi) with an average of 0.913 ± 0.030 (standard deviation) (Table 3). Average genetic similarity of a cultivar across all other cultivars was found to be minimum for Kiran (0.856). In other words, Kiran was found to be most diverse cultivar followed by Garima. Cultivars LS54 and KL1, each with a value of 0.929 shared the maximum genome homology at the investigated loci with other cultivars followed by for cultivars Shekhar and Neelum (0.928 each).

UPGMA based clustering of all 21 cultivars is shown in Figure 2. Four arbitrary clusters are evident from the dendrogram, Cluster I being the largest with two sub-clusters in it, followed by Cluster II. The other two clusters (III and IV) were equal sized each having two cultivars. All four white-flowered cultivars (Sweta, KL1, Shubhra and LC54) were positioned in Cluster Ia. Two of the three yellow-seeded cultivars (KL1 and KL 210) were also placed in Cluster Ia. The third yellow-seeded cultivar in the study (LC185) grouped with cultivars of Cluster II. The two cultivars of the cluster Ib were very recently released ones. The cultivars of the Cluster IV were very distinct from all other cultivars with a very sound bootstrap support (100). Kiran of this cluster has exotic pedigree in its blood which might have led to this distinctness. The pedigree for the other cultivar of this cluster (NL-97) is not available which, otherwise, would have substantiated this observation. Analysis of molecular

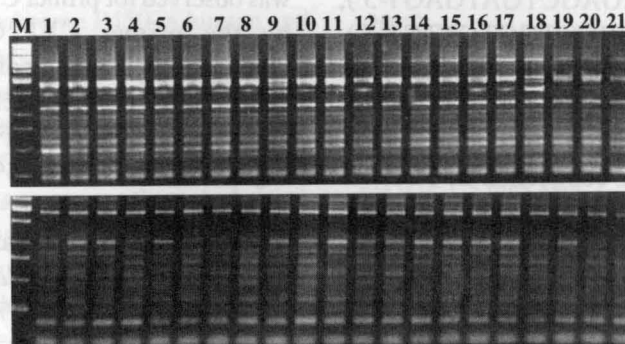


Fig. 1. Profiling of 21 linseed (*Linum usitatissimum* L.) cultivars using primer combination CYP2C19F/ CYP1A1R (a) and CYP2C19F/ Heme2B6. M is 1 kb molecular weight standard and lanes 1 to 21 are cultivars names as given in Table 1.

Table 3. Pair-wise Jaccard's (1908) genetic similarity estimates among 21 linseed (*Linum usitatissimum* L.) cultivars

	Padmini	Parvati	Rashmi	Shekhar	Sheela	Shubhra	Sweta	T-397	NL-97	Neelum	Meera	LC185	LC54	Laxmi	KL210	KL3	KL1	Kiran	Jawahar-552	Gaurav	Garima
Padmini	1.000																				
Parvati	0.921	1.000																			
Rashmi	0.968	0.920	1.000																		
Shekhar	0.952	0.904	0.921	1.000																	
Sheela	0.928	0.926	0.927	0.959	1.000																
Shubhra	0.952	0.919	0.921	0.967	0.943	1.000															
Sweta	0.937	0.873	0.921	0.951	0.942	0.935	1.000														
T-397	0.937	0.903	0.936	0.951	0.942	0.951	0.951	1.000													
NL-97	0.886	0.913	0.886	0.899	0.890	0.899	0.869	0.884	1.000												
Neelum	0.937	0.934	0.936	0.951	0.942	0.967	0.904	0.935	0.913	1.000											
Meera	0.913	0.958	0.898	0.927	0.934	0.927	0.911	0.896	0.921	0.927	1.000										
LC185	0.914	0.927	0.929	0.898	0.888	0.883	0.912	0.927	0.906	0.897	0.904	1.000									
LC54	0.937	0.919	0.936	0.951	0.942	0.935	0.935	0.967	0.898	0.951	0.896	0.943	1.000								
Laxmi	0.921	0.887	0.920	0.951	0.942	0.919	0.934	0.934	0.883	0.950	0.895	0.911	0.967	1.000							
KL210	0.929	0.911	0.928	0.943	0.950	0.927	0.911	0.927	0.891	0.959	0.919	0.889	0.943	0.975	1.000						
KL3	0.913	0.942	0.912	0.911	0.933	0.896	0.911	0.911	0.905	0.926	0.934	0.934	0.942	0.942	0.934	1.000					
KL1	0.953	0.905	0.922	0.968	0.943	0.952	0.952	0.952	0.900	0.936	0.928	0.913	0.952	0.935	0.944	0.927	1.000				
Kiran	0.881	0.864	0.853	0.866	0.828	0.866	0.837	0.837	0.931	0.851	0.871	0.872	0.837	0.822	0.830	0.842	0.867	1.000			
Jawahar-552	0.906	0.903	0.876	0.905	0.895	0.905	0.935	0.935	0.919	0.884	0.874	0.911	0.927	0.919	0.888	0.866	0.926	0.921	0.879	1.000	
Gaurav	0.930	0.882	0.929	0.898	0.904	0.913	0.898	0.913	0.878	0.928	0.875	0.906	0.913	0.912	0.920	0.889	0.914	0.859	0.868	1.000	
Garima	0.889	0.917	0.888	0.887	0.908	0.918	0.871	0.902	0.881	0.933	0.909	0.879	0.902	0.901	0.925	0.924	0.903	0.820	0.871	0.926	1.000
Average	0.925	0.911	0.916	0.928	0.923	0.925	0.914	0.924	0.896	0.928	0.913	0.908	0.929	0.919	0.921	0.918	0.929	0.856	0.899	0.903	0.898
similarity±	±	±	±	±	±	±	±	±	±	±	±	±	±	±	±	±	±	±	±	±	±
Standard deviation	0.923	0.911	0.925	0.929	0.930	0.926	0.931	0.929	0.915	0.928	0.920	0.919	0.908	0.929	0.934	0.932	0.923	0.925	0.921	0.921	0.926

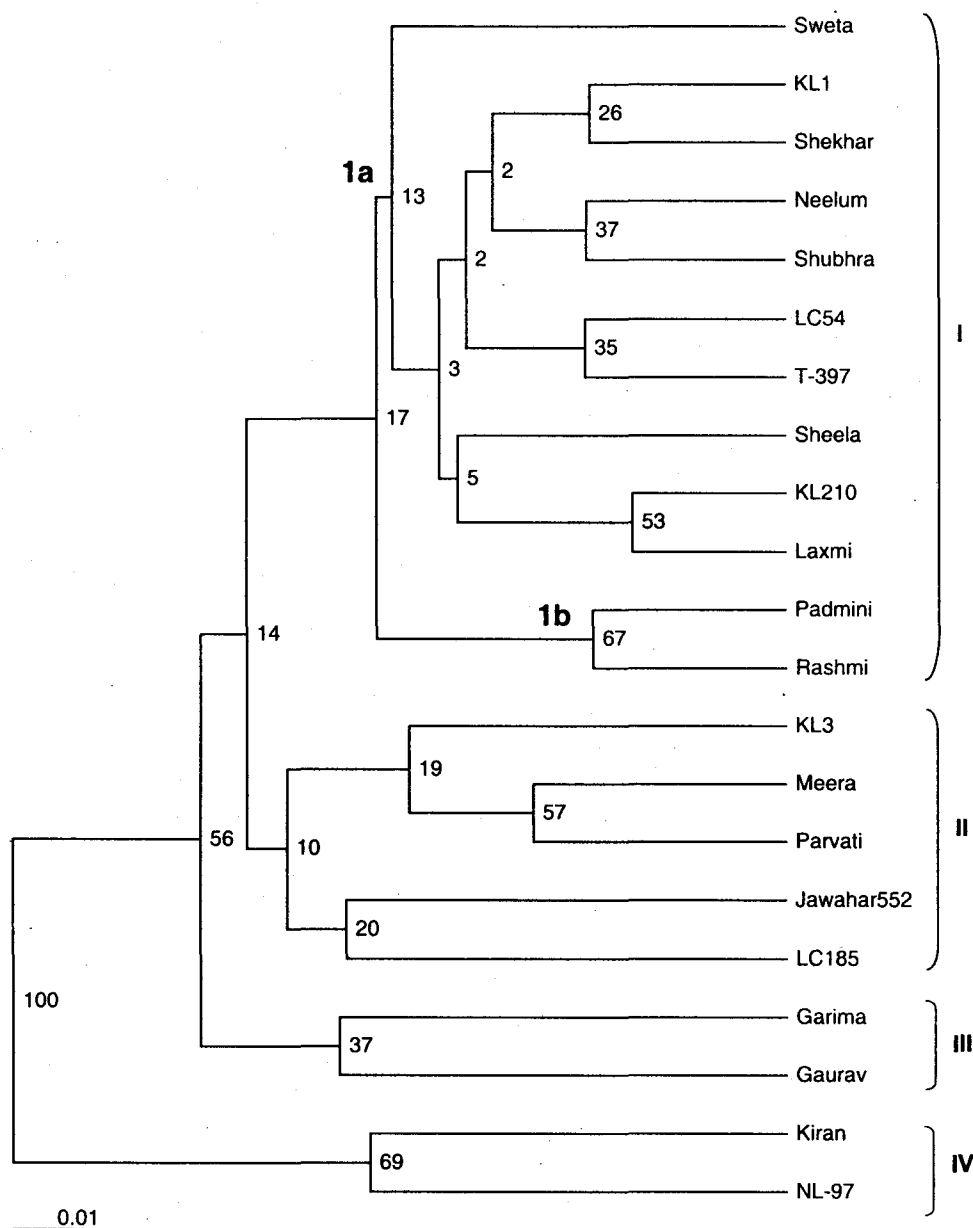


Fig. 2. UPGMA dendrogram for 21 linseed (*Linum usitatissimum* L.) cultivars using 136 markers generated by 15 PBA primers and Jaccard's similarity estimates. The numbers inside the figure denote per cent bootstrap support for each node.

variance (AMOVA) was done by grouping these cultivars into populations based on year of release (pre-1990 and post-1990), flower colour (white and blue), seed size (large, medium and small), seed colour (yellow and brown) and yield (less than 1000 kg/hectare and more than 1000 kg/hectare). Most of the variation in all these cases could be attributed to within population variation as the variation among these created groups was negligible.

The polymorphism level was quite low in the linseed cultivars using PBAs markers. The utility of these markers

need to be assessed on crop-by-crop basis as these have revealed high polymorphism in other crops like chilli, tomato, eggplant etc. Low level of polymorphism revealed by these markers in intra-specific investigation in linseed suggests their utility for higher taxonomic level studies, which needs to be proved in the genus *Linum*.

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Morphological Variability and Identification of Minimum Descriptors in Chilli Based on Principal Component Analysis

R Borgohain and J Devi

Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat-785 013 (Assam)

Principal Component Analysis (PCA) was carried out in thirty three chilli accessions to assess the relative contribution of different morphological characters to the total variability and to establish a list of minimum descriptors. Eight principal components (PCs) accounting for 88.19% of the total variability among the accessions were extracted. The first PC accounted for 33.08% and the second PC accounted for 17.03% of the total variability and were mainly associated with seedling and fruit characters respectively. Vegetative characters were distributed mostly in the first four PCs. Scatter plot of the accessions drawn from the first two principal components revealed the characters which could discriminate among species and helped in grouping them into different clusters. Twenty eight minimum morphological descriptors were identified on the basis of their correlation with other characters and contribution to the total variability as revealed by PCA and were expected to be highly discriminating. These morphological descriptors would help in quick characterization of chilli germplasm.

Key words: *Capsicum annum*, *Capsicum chinense*, *Capsicum frutescens*, Principal component Analysis, Minimum descriptors

The intra and interspecific variability in chilli is tremendous and many characters exhibit parallel variation across the species (Pickersgill, 1971) which often makes morphology based classification difficult. For the study of such morphologically complex populations, multivariate analysis combines the capacity to provide a synthetic summary of the most relevant traits and can help in assessing the relative importance of different characters to the total variability of the population (Camussi, 1979, Abadie *et al.*, 1998). Multivariate analysis of agronomic and morphological characters has been used for the characterization, evaluation and classification of germplasm in crops like beans, chickpeas, onion, peanuts, colocasia and maize (Costeñeiras, 1992, Fraga *et al.*, 1996; Shagardsky *et al.*, 1996; Fundora *et al.*, 1997; Rodriguez Manzano *et al.*, 2001).

The International Plant Genetic Resources Institute (IPGRI) has published the complete descriptors of capsicum which tremendously help in detail characterization and evaluation of capsicum germplasm. However, characterization of a large number of genotypes using numerous morphological traits is often tedious and a time consuming proposition, albeit, detail characterization of germplasm often requires considerably large number of morphological descriptors in view of the tremendous morphological variations apparent intra and interspecifically in chilli. However, for preliminary characterization and quick discrimination between

genotypes, a basic set of descriptors having uniform expressivity across environments and easy visual scorability would be sufficient for all practical point of view.

In this work, Principal Component Analysis (PCA) was carried out using several morphological traits to determine the relative contribution of these characters towards the total variability in chilli and to establish a list of minimum descriptors for quick characterization and genotype identification.

Materials and Methods

Thirty three chilli accessions representing a wide range of variation in chilli were included in the analysis (Fig. 1). Out of these, 21 accessions belonged to *C. annum* L. (designated by 'A' within parenthesis in Fig. 1) 6 to *C. chinense* Jacq. (designated by 'C' within parenthesis) and 6 to *C. frutescens* L. (designated by 'F' within parenthesis). The experiment was conducted in the Experimental Farm of Assam Agricultural University, Jorhat, Assam during winter seasons of 2001-2002 and 2002-2003. Materials were evaluated in 5 x 2 m² plots and seedlings were transplanted in 50 x 40 cm spacing.

For morphological characterization forty characters (Table 1) were considered from the Capsicum Descriptors published by IPGRI (1995). Out of these, nine were considered useful primarily in separating species, while other characters included attributes which were helpful in morphological characterization within species. Nineteen of these characters were qualitative while the rest were quantitative in nature. The score or weightages as

E-mail: rupam@aau.ac.in

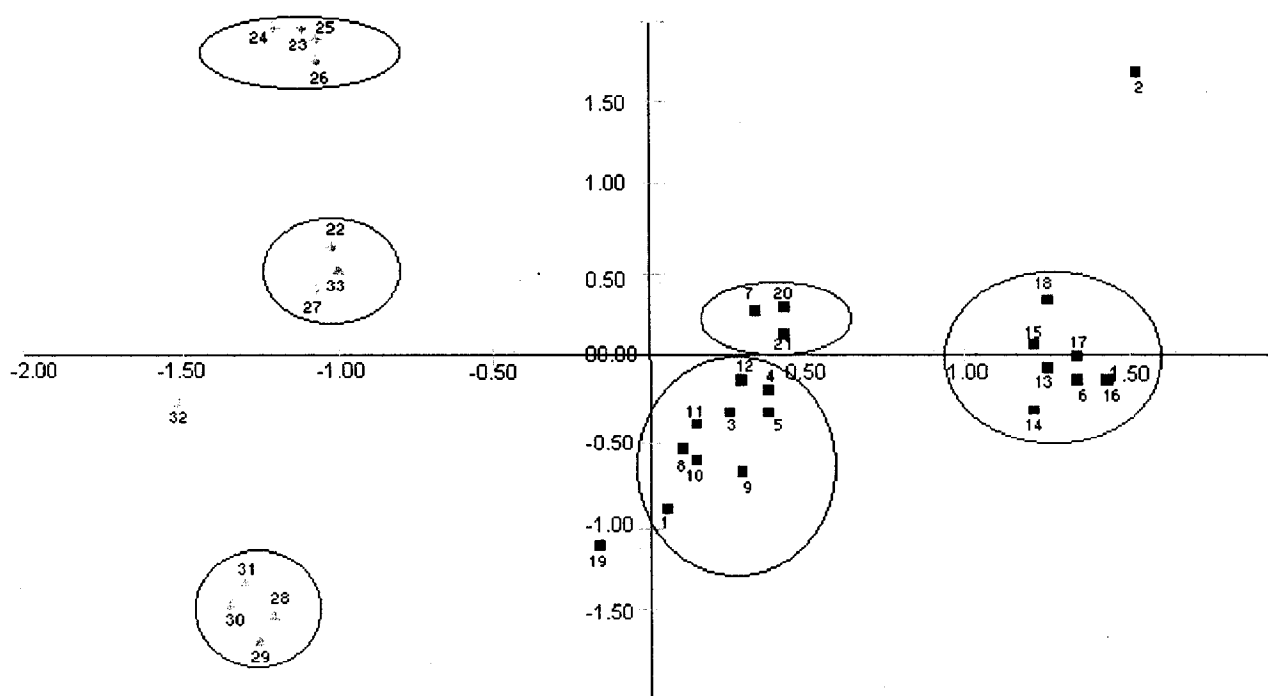


Fig. 1: Plot of the cultivars representing *C. annuum* L., *C. chinense* Jacq. and *C. frutescens* L. on the first two components recognized by Principal Component Analysis. 1 = ACC(A)-01, 2 = ACC(A)-02, 3 = ACC(A)-03, 4 = ACC(A)-04, 5 = ACC(A)-05, 6 = ACC(A)-06, 7 = ACC(A)-07, 8 = ACC(A)-08, 9 = ACC(A)-09, 10 = ACC(A)-10, 11 = ACC(A)-11, 12 = ACC(A)-12, 13 = ACC(A)-13, 14 = ACC(A)-14, 15 = ACC(A)-14-1, 16 = ACC(A)-14-2, 17 = ACC(A)-14-3, 18 = ACC(A)-15, 19 = ACC(A)-16, 20 = ACC(A)-17, 21 = ACC(A)-18, 22 = ACC(C)-19, 23 = ACC(C)-20, 24 = ACC(C)-21, 25 = ACC(C)-22, 26 = ACC(C)-23, 27 = ACC(C)-24, 28 = ACC(F)-25, 29 = ACC(F)-26, 30 = ACC(F)-27, 31 = ACC(F)-28, 32 = ACC(F)-29, 33 = ACC(F)-30

recommended for each of the qualitative characters in the Capsicum Descriptors and actual numerical data for the quantitative characters were used for numerical taxonomic study.

Principal Component Analysis (PCA) with the morphological data was carried out following method described by Sneath and Sokal (1973) and SAS Institute, Inc. (1985). In this procedure, first a standardized (mean = 0 and variance = 1) correlation matrix between the characters of all the test individuals was calculated to transform the original variables into a new set of independent variables. The principal components were then calculated from this standardized correlation matrix. The mean values from the highest and lowest eigenvectors were used as the threshold for selection of the characters contributing most to the total variability (Rodríguez Manzano *et al.*, 2001). The statistical computation of PCA was performed using statistical software package "SPSS for MS Windows Release 7.5".

Results and Discussion

The correlation coefficients among the forty morphological characters derived from standardization of original data

were presented in Table 2. The large number of observation raised the test power, giving significance to most of the correlation; hence, only values above 0.6 are discussed. Several seedling characters viz., cotyledonous leaf colour, cotyledonous leaf length and width, cotyledonous leaf shape, hypocotyl colour and hypocotyl pubescence appeared highly correlated among themselves besides exhibiting positive association with several vegetative, inflorescence and fruit characters. Most of the vegetative characters viz., plant height, branching habit, growth habit, leaf colour, leaf pubescence type and density, leaf length and width were not associated among themselves and they mostly showed association with seedling characters only. Among the inflorescence characters, corolla length was found to be significantly associated with anther colour and calyx margin shape.

The matrix of eigenvectors and values of the principal components (PC) derived from the correlation matrix are presented in Table 3. Altogether eight (8) PCs were extracted accounting for 88.19% of the total variability of the chilli accessions. However, only the first four principal components are discussed as they explained 71.16% of the total variation.

Table 1. Morphological characters of *Capsicum* species recorded for the study along with their scores/ weightage (as per IPGRI descriptor, 1995)

I. Seedling		
(i)	Hypocotyl colour	: Green (1), ¼ purple from the base (2), ½ purple from the base (3), purple (4)
(ii)	Cotyledonous leaf length	: (mm)
(iii)	Cotyledonous leaf width	: (mm)
(iv)	Cotyledonous leaf shape	: Deltoid (3), Ovate (5), Lanceolate (7)
(v)	Cotyledonous leaf colour	: Light green (3), Green (5), Dark green (7), Other (9)
(vi)	Hypocotyl pubescence	: Glabrous (0), Sparse (3), Intermediate (5), Abundant (7)
II. Vegetative		
(vii)	Plant growth habit	: Prostrate (3), Compact (5), Erect (7)
(viii)	Plant height	: (cm)
(ix)	Stem pubescence density (at 2 nodes below the shoot when first fruit turning red)	: Glabrous (0), Sparse (3), Intermediate (5), Abundant (7)
(x)	Stem colour	: Green (1), Green with few purple strip (2), Green with more purple strip (3), Purple (4), Others (5)
(xi)	Leaf pubescence density (the youngest mature leaves when first fruit turning red)	: Glabrous (0), Sparse (3), Intermediate (5), Abundant (7)
(xii)	Leaf pubescence type	: Short (3), Intermediate (5), Long (7)
(xiii)	Mature leaf length	: (cm)
(xiv)	Mature leaf width	: (cm)
(xv)	Leaf shape	: Deltoid (3), Ovate (5), Lanceolate (7)
(xvi)	Leaf colour	: Yellow (1), Light green (2), Green (3), Dark green (4) Others (5)
(xvii)	Branching habit	: None (0), Sparse (3), Intermediate (5), Abundant (7)
III. Inflorescence and fruit		
(xviii)	Number of pedicels per axil	: One per axil (1), Two pedicels per axil (2), Three or more pedicel per axil (3), Many pedicels in bunches but each in individual axil (4)
(xix)	Pedicel position at anthesis	: Pendant (3), Intermediate (5), Erect (7)
(xx)	Angle between flower and pedicel	: 0° (3), 45° (5), 90° (7), >90° (9)
(xxi)	Corolla colour	: White (1), Light yellow (2), Yellow (3), Yellow-green (4), White with purple base (5), White with purple margin (6), Purple (7), Others (8)
(xxii)	Corolla length	: (mm)
(xxiii)	Anther colour	: Yellow (1), Pale blue (2), Blue (3), Purple (4), Others (5)
(xxiv)	Calyx margin shape	: Smooth (3), Intermediate (5), Dentate (7)
(xxv)	Annular constriction at junction of calyx and peduncle	: Absent (0), Not-clear (3), Clear (5), distinct and uniform in the whole plant (7)
(xxvi)	Fruit position	: Declining (3), Intermediate (5), Erect (7)
(xxvii)	Fruit colour in immature stage	: Green (1), Yellow (2), Orange (3), Red (4), Purple (5), Brown (6), Black (7), Others (8)
(xxviii)	Fruit colour in mature stage	: Green (1), Yellow (2), Orange (3), Orange-red (4), Red (5), Purple (6), Brown (7), Black (8), Others (9)
(xxix)	Fruit length	: (cm)
(xxx)	Fruit width	: (cm)
(xxxi)	Fruit per plant	: (Nos)
(xxxii)	Fruit weight (fresh)	: (g)
(xxxiii)	Fruit weight (dry)	: (g)
(xxxiv)	Fruit shape	: Elongate (1), Oblate (2), Round (3), Conical (4), Campanulate (5), Bell or blocky (6), Others (7)
(xxxv)	Fruit cross-sectional corrugation	: Smooth (0), Slightly corrugated (3), Intermediate (5), Corrugated (7)
(xxxvi)	Fruit pungency	: Not pungent (0), Low (3), Intermediate High (7)
(xxxvii)	Fruit persistence	: Deciduous (0), Slight (3), Intermediate (5), Persistent (7)
IV. Seed		
(xxxviii)	Seed colour	: Straw colour (1), Black/brown (2), Others (3)
(xxxix)	1000 seed weight	: (g)
(xxxx)	Number of seeds/fruit	: Nos.

The first component accounting for 33.08% of the variation was mainly linked to all the seedling characters along with few vegetative, inflorescence and fruit characters. The characters showing greatest variability in this component were cotyledonous leaf length,

cotyledonous leaf colour, cotyledonous leaf shape, cotyledonous leaf breadth, hypocotyl colour, hypocotyl pubescence, leaf colour, leaf shape, stem colour, calyx margin shape, corolla colour, anther colour, immature fruit colour and number of seeds/fruit. The association

Table 2. Correlation co-efficients among 40 morphological characters of chilli

S.No.	Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Anther colour		-0.562	-0.399	0.226	-0.590	0.236	0.855	0.919	0.929	0.863	0.747	0.784	0.155	-0.615	0.768	0.086	-0.058	-0.036	-0.074
2	Annular constriction	-0.562**		-0.108	0.313	0.538	0.144	-0.439	-0.488	-0.611	-0.630	-0.251	-0.333	0.104	0.868	-0.243	-0.003	0.319	0.175	-0.117
3	Angle between flower and pedicel	-0.399*	-0.108		-0.281	0.451	-0.092	-0.531	-0.360	-0.518	-0.342	-0.619	-0.607	-0.582	-0.053	-0.304	-0.439	-0.555	-0.519	0.394
4	Branching habit	0.226	0.313	-0.281		0.044	0.153	0.144	0.099	0.119	0.147	0.168	0.441	0.125	0.307	0.199	-0.039	0.121	0.229	-0.309
5	Fruticendency	-0.590**	0.538**	0.451**	0.044		0.325	-0.675	-0.697	-0.822	-0.749	-0.696	-0.728	-0.520	0.573	-0.156	0.208	-0.350	-0.322	0.129
6	Corolla colour	0.236	0.144	-0.092	0.153	0.325		0.181	0.244	0.021	-0.286	0.197	-0.219	-0.142	0.100	0.786	0.203	-0.035	-0.315	-0.058
7	Corolla length (mm)	0.855**	-0.439*	-0.531**	0.144	-0.675**	0.181		0.848	0.878	0.752	0.789	0.750	0.276	-0.444	0.621	0.179	0.108	0.136	-0.105
8	Coryledonous leaf colour	0.919**	-0.488**	-0.360*	0.099	-0.697**	0.244	0.848**		0.921**	0.905	0.828	0.841	0.388	-0.634	0.583	0.067	0.167	0.189	-0.182
9	Coryledonous leaf length (mm)	0.929**	-0.611**	-0.518**	0.119	-0.822**	0.021	0.878**	0.921**		0.905	0.828	0.841	0.388	-0.634	0.583	0.067	0.167	0.189	-0.182
10	Coryledonous leaf shape	0.863**	-0.630**	-0.342	0.147	-0.749**	-0.286	0.752**	0.778**	0.905**		0.630**	0.887	0.222	-0.659	0.346	-0.022	-0.041	0.126	-0.041
11	Coryledonous leaf breadth (mm)	0.747**	-0.251	-0.619**	0.168	-0.696**	0.197	0.789**	0.816**	0.828**	0.630**		0.658	0.576	-0.250	0.575	0.095	0.444	0.291	-0.309
12	Calyx margin shape	0.784**	-0.333	-0.607**	0.441**	-0.728**	-0.219	0.750**	0.689**	0.841**	0.887**	0.658**		0.349	-0.390	0.337	-0.021	0.155	0.295	-0.185
13	Dry fruit weight (g)	0.155	0.104	-0.582**	0.125	-0.520**	-0.142	0.276	0.319	0.388*	0.222	0.576**	0.369*		0.151	-0.003	0.117	0.916	0.835	-0.591
14	Fruit cross-sectional corrugation	-0.615**	0.868**	-0.053	0.307	0.573**	0.100	-0.444**	-0.566**	-0.634**	-0.659**	-0.250	-0.390*	0.151		-0.335	0.120	0.358	0.309	-0.317
15	Fruit colour (immature)	0.768**	-0.243	-0.304	0.199	-0.156	0.786**	0.621**	0.724**	0.583**	0.346	0.575**	0.337	-0.003	-0.335		0.124	-0.073	-0.247	-0.063
16	Fruit colour (mature)	0.086	-0.003	-0.439*	-0.039	0.208	0.203	0.179	-0.026	0.067	-0.022	0.095	-0.021	0.117	0.120	0.124		0.123	0.283	-0.227
17	Fresh fruit weight (g)	-0.058	0.319	-0.555**	0.121	-0.350*	-0.035	0.108	0.138	0.167	-0.041**	0.444	0.155**	0.916*	0.358	-0.073	0.123		0.801**	-0.700
18	Fruit length (cm)	-0.036	0.175	-0.519**	0.229	-0.322	-0.315	0.136	0.054	0.189	0.126	0.291	0.295	0.835**	0.309	-0.247	0.283	0.801**		-0.700
19	Fruit position	-0.074	-0.117	0.394*	-0.309	0.129	-0.058	-0.105	-0.121	-0.182	-0.041	-0.309	-0.185	-0.591**	-0.317	-0.063	-0.227	-0.565**	-0.700**	
20	Fruit/plant	-0.240	-0.357*	0.681**	-0.536**	0.368*	0.050	-0.399*	-0.289	-0.336	-0.258	-0.508**	-0.603**	-0.581**	-0.385*	-0.108	0.000	-0.573**	-0.545**	0.397*
21	Fruit/persistence	0.022	-0.120	-0.055*	-0.064	0.292	0.066	-0.053	-0.130	-0.036	-0.006	-0.298	-0.066	-0.105	-0.141	0.088	0.599**	-0.192	0.118	-0.079
22	Fruit shape	-0.074	0.414*	0.019	0.363*	0.129	0.336	-0.055	0.005	-0.137	-0.266	0.193	-0.069	0.150	0.471**	0.164	-0.269	0.255	-0.008	-0.143
23	Fruit width (cm)	-0.176	0.647**	-0.438*	0.365*	0.033	0.253	-0.024	-0.074	-0.130	-0.311	0.216	0.028	0.537**	0.647**	0.054	-0.038	0.717**	0.433*	-0.288
24	Hypocotyl colour	0.762**	-0.267	-0.235	0.294	-0.136	0.752**	0.634**	0.716**	0.583**	0.372*	0.529**	0.361*	0.001	-0.326	0.938**	0.172	-0.074	-0.191	-0.102
25	Hypocotyl pubescence	0.689**	-0.435*	-0.130	0.104	-0.536**	0.012	0.383*	0.704**	0.684**	0.677**	0.558**	0.530**	0.267	-0.563**	0.467**	-0.291	0.102	-0.010	-0.061
26	Leaf colour	0.687**	-0.142	-0.318	0.519**	-0.349*	0.229	0.546**	0.707**	0.621**	0.564**	0.541**	0.628**	0.261	-0.174	0.557**	-0.026	0.141	0.188	-0.368*
27	Leaf pubescence density	0.132	0.088	0.077	0.363*	-0.126	-0.062	-0.070	0.135	0.086	0.153	0.000	0.223	0.022	-0.048	0.109	-0.541**	-0.069	-0.127	0.046
28	Leaf pubescence type	0.205	-0.037	0.104	0.374*	-0.191	-0.088	-0.013	0.203	0.164	0.238	0.062	0.281	0.049	-0.116	0.121	-0.532**	-0.074	-0.118	0.019
29	Leaf shape	0.734**	-0.681**	-0.403*	0.009	-0.588**	-0.127	0.633**	0.610**	0.763**	0.790**	0.378	0.689**	0.063	-0.740**	0.390*	0.178	-0.180	0.059	-0.061
30	Mature leaf length (cm)	0.133	0.302	-0.091	0.507**	-0.052	0.192	0.186	0.151	0.061	0.047	0.057	0.310	0.092	0.240	0.181	-0.346	0.157	0.098	-0.127
31	Mature leaf width (cm)	-0.288	0.653**	-0.007	0.280	0.251	0.275	-0.115	-0.192	-0.343	-0.416*	-0.131	-0.137	0.102	0.571**	-0.015	-0.231	0.291	0.101	0.012
32	No. pedicels/axil	-0.505**	0.352*	0.110	-0.306	0.169	-0.054	-0.162	-0.356*	-0.422*	-0.469**	-0.367*	-0.381*	-0.112	0.287	-0.326	0.032	-0.018	0.033	0.192
33	No. of seed/fruit	0.832**	-0.500**	-0.411*	0.162	-0.681**	0.015	0.662**	0.819**	0.862**	0.793**	0.640**	0.754**	0.378*	-0.548**	0.549**	-0.030	0.141	0.136	-0.134
34	Plant Growth habit	0.363*	-0.432*	0.200	0.028	-0.247	-0.081	0.115	0.335	0.330	0.395*	0.180	0.183	0.065	-0.546**	0.198	-0.200	-0.071	-0.021	-0.052
35	Plant height (cm)	0.388*	-0.183	-0.074	-0.037	-0.257	0.205	0.383*	0.464**	0.364*	0.285	0.247	0.226	0.110	-0.395*	0.366*	0.128	0.038	0.019	0.007
36	Pedicel position at anthesis	-0.441**	-0.039	0.915**	-0.227	0.478**	-0.119	-0.643**	-0.424*	-0.548**	-0.378*	-0.646**	-0.609**	-0.502**	0.021	-0.337	-0.422*	-0.470	-0.458**	0.280
37	Stem colour	0.773**	-0.300	-0.252	0.229	-0.292	0.680**	0.667**	0.754**	0.617**	0.418*	0.630**	0.406*	-0.016*	-0.366**	0.902**	-0.043	-0.069	-0.305	0.052
38	Seed colour	-0.863**	0.630**	0.342	-0.147	0.749**	0.286	-0.752**	-0.778**	-0.905**	-1.000**	-0.630**	-0.887**	-0.222**	0.659**	-0.346**	0.022	0.041	-0.126	0.041
39	Stem pubescence density	0.158	0.068	0.355*	0.022	0.064	0.243	-0.127	0.237	0.016	0.027	-0.015	-0.069	-0.155	-0.164	0.334	-0.549**	-0.207	-0.381*	0.245
40	1000 seed weight (g)	0.058	0.013	-0.262	0.076	-0.311	-0.148	0.110	0.206	0.225	0.141	0.289	0.232	0.482**	0.121	-0.059	-0.043	0.381	0.462**	-0.478**

Table 2. Contd.

S.No.	Characters	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	Anther colour	-0.240	-0.022	-0.074	-0.176	0.762	0.689	0.687	0.132	0.205	0.734	0.133	-0.288	-0.505	0.832	0.363	0.388	-0.441	0.773	-0.863	0.158	0.058
2	Annular constriction ^a	-0.357	-0.120	0.414	0.647	-0.267	-0.435	-0.142	0.088	-0.037	-0.681	0.302	0.653	0.352	-0.509	-0.432	-0.183	-0.039	-0.300	0.630	0.068	0.013
3	Angle between flower and pedicel	0.681	-0.055	0.019	-0.438	-0.235	-0.130	-0.318	0.077	0.104	-0.403	-0.091	-0.007	0.110	-0.411	0.200	-0.074	0.915	-0.252	0.342	0.355	-0.262
4	Branching habit	-0.536	-0.064	0.363	0.365	0.294	0.104	0.519	0.363	0.374	0.009	0.507	0.280	-0.306	0.162	0.028	-0.037	-0.227	0.229	-0.147	0.022	0.076
5	Fruit pungency	0.368	0.292	0.129	0.033	-0.136	-0.536	-0.349	-0.126	-0.191	-0.588	-0.052	0.251	0.169	-0.681	-0.247	-0.257	0.478	-0.292	0.749	0.064	-0.311
6	Corolla colour	0.050	0.066	0.336	0.253	0.752	0.012	0.229	-0.062	-0.088	-0.127	0.192	0.275	-0.054	0.015	-0.081	0.205	-0.119	0.680	0.286	0.243	-0.148
7	Corolla length (mm)	-0.399	-0.053	-0.055	-0.024	0.634	0.383	0.546	-0.070	-0.013	0.633	0.186	-0.115	-0.162	0.662	0.115	0.383	-0.643	0.667	-0.752	-0.127	0.110
8	Cotyledonous leaf colour	-0.289	-0.130	0.005	-0.074	0.716	0.704	0.707	0.135	0.203	0.610	0.151	-0.192	-0.356	0.819	0.335	0.464	-0.424	0.754	-0.778	0.237	0.206
9	Cotyledonous leaf length (mm)	-0.336	-0.036	-0.137	-0.130	0.583	0.684	0.621	0.086	0.164	0.763	0.061	-0.343	-0.422	0.862	0.320	0.364	-0.548	0.617	-0.905	0.016	0.225
10	Cotyledonous leaf shape	-0.258	-0.006	-0.266	-0.311	0.372	0.677	0.564	0.153	0.238	0.790	0.047	-0.416	-0.469	0.793	0.395	0.285	-0.378	0.418	-1.000	0.027	0.141
11	Cotyledonous leaf breadth (mm)	-0.508	-0.298	0.193	0.206	0.529	0.558	0.541	0.000	0.062	0.378	0.057	-0.131	-0.367	0.690	0.180	0.247	-0.606	0.630	-0.630	-0.005	0.289
12	Calyx margin shape	-0.603	-0.066	-0.069	0.028	0.361	0.530	0.628	0.223	0.281	0.689	0.310	-0.137	-0.381	0.754	0.183	0.226	-0.609	0.406	-0.887	-0.069	0.232
13	Dry fruit weight (g)	-0.581	-0.105	0.150	0.537	0.001	0.267	0.261	0.022	0.049	0.063	0.092	0.102	-0.112	0.378	0.065	0.110	-0.502	-0.016	-0.222	-0.155	0.482
14	Fruit cross-sectional corrugation	-0.385	-0.141	0.471	0.647	-0.326	-0.563	-0.174	-0.048	-0.116	-0.740	0.240	0.571	0.287	-0.548	-0.546	-0.395	0.021	-0.366	0.659	-0.164	0.121
15	Fruit colour (immature)	-0.108	0.068	0.164	0.054	0.938	0.467	0.557	0.109	0.121	0.390	0.181	-0.015	-0.326	0.549	0.198	0.366	-0.337	0.902	-0.346	0.334	-0.059
16	Fruit colour (mature)	0.000	0.599	-0.269	-0.038	0.172	-0.291	-0.026	-0.541	-0.532	0.178	-0.346	-0.231	0.032	-0.030	-0.200	0.128	-0.422	-0.043	0.022	-0.549	-0.043
17	Fresh fruit weight (g)	-0.573	-0.192	0.255	0.717	-0.074	0.102	0.141	-0.069	-0.074	-0.180	0.157	0.291	-0.018	0.141	-0.071	0.038	-0.470	-0.069	0.041	-0.207	0.381
18	Fruit length (cm)	-0.545	0.118	-0.008	0.433	-0.191	-0.010	0.188	-0.127	-0.118	0.059	0.098	0.101	0.033	0.136	-0.021	0.019	-0.458	-0.306	-0.126	-0.381	0.462
19	Fruit position	0.397	-0.079	-0.143	-0.288	-0.102	-0.061	-0.368	0.046	0.019	-0.061	-0.127	0.012	0.192	-0.134	-0.052	0.007	0.280	0.052	0.041	0.245	-0.478
20	Fruit/plant	0.280	-0.364	-0.648	-0.094	-0.094	-0.064	-0.463	-0.157	-0.156	-0.058	-0.459	-0.364	0.002	-0.323	0.327	0.082	0.648	-0.141	0.258	0.154	-0.359
21	Fruit persistence	0.280	-0.525	-0.339	-0.339	0.173	-0.096	-0.021	-0.160	-0.208	0.314	-0.271	-0.244	0.154	-0.048	0.120	0.374	-0.108	-0.207	0.006	-0.101	-0.012
22	Fruit shape	-0.364*	-0.525**	0.605	0.605	0.085	-0.165	0.122	0.249	0.284	-0.591	0.377	0.522	-0.019	0.119	-0.194	-0.180	0.097	0.161	0.266	0.087	0.025
23	Fruit width (cm)	-0.648**	-0.339	0.605**	-0.007	-0.007	-0.187	0.051	0.094	0.043	-0.483	0.497	0.723	0.118	-0.042	-0.351	-0.120	-0.348	0.070	0.311	-0.060	0.150
24	Hypocotyl colour	-0.094	0.173	0.085	-0.007	0.473	0.634	0.634	0.037	0.066	0.384	0.275	0.030	-0.346	0.474	0.201	0.454	-0.323	0.891	-0.372	0.271	-0.008
25	Hypocotyl pubescence	-0.064	-0.096	-0.165	-0.187	0.473**	0.568	0.568	0.350	0.385	0.530	-0.011	-0.355	-0.671	0.662	0.583	0.253	-0.109	0.519	-0.677	0.529	0.130
26	Leaf colour	-0.463**	-0.021	0.122	0.051	0.634**	0.568**	0.568**	0.243	0.294	0.441	0.314	-0.074	-0.440	0.606	0.206	0.246	-0.288	0.555	-0.564	0.206	0.242
27	Leaf pubescence density	-0.157	-0.160	0.249	0.094	0.037	0.350*	0.243	0.972	0.083	0.212	0.212	0.101	-0.087	0.321	0.247	-0.007	0.119	0.121	-0.153	0.563	0.125
28	Leaf pubescence type	-0.156	-0.208	0.284	0.043	0.066	0.385*	0.294	0.972**	0.119	0.211	0.211	0.035	-0.184	0.406	0.317	-0.001	0.144	0.164	-0.238	0.502	0.158
29	Leaf shape	-0.058	0.314	-0.591**	-0.483**	0.384*	0.530**	0.441**	0.083	0.119	-0.121	-0.121	-0.585	-0.310	0.625	0.301	0.252	-0.435	0.352	-0.790	-0.016	0.027
30	Mature leaf length (cm)	-0.459**	-0.271	0.377*	0.497**	0.275	-0.011	0.314	0.212	0.211	-0.121	-0.121	0.772	0.088	0.018	-0.189	0.184	-0.157	0.318	-0.047	0.168	0.004
31	Mature leaf width (cm)	-0.364*	-0.244	0.522**	0.723**	0.030	-0.355*	-0.074	0.101	0.035	-0.585**	0.772**	0.405*	-0.470	-0.327	-0.351	0.104	-0.083	0.070	0.416	0.102	0.005
32	No. of pedicels/axil	0.002	0.154	-0.019	0.118	-0.346	-0.671**	-0.440**	-0.087	-0.184	-0.310	0.088	0.405*	-0.470	-0.439	0.197	-0.019	-0.389	0.469	-0.060	0.004	0.008
33	No. of seed/ fruit	-0.323	-0.048	0.119	-0.042	0.474**	0.662**	0.606**	0.321	0.406*	0.625**	0.018	-0.327	-0.470**	0.344	0.271	-0.345	0.490	-0.793	0.161	0.198	0.198
34	Plant growth habit	0.327	0.120	-0.194	-0.351*	0.201	0.583**	0.206	0.247	0.317	0.301	-0.189	-0.351*	-0.439*	0.344	0.459	0.174	-0.345	0.165	-0.395	0.280	0.039
35	Plant height (cm)	0.082	0.374*	-0.180	-0.120	0.454**	0.253	0.246	-0.007	-0.001	0.252	0.184	0.104	0.197	0.271	0.459**	-0.222	0.305	-0.285	0.229	0.104	0.104
36	Pedicel position at anthesis	0.648**	-0.108	0.097	-0.348*	-0.323	-0.109	-0.288	0.119	0.144	-0.435*	-0.157	-0.083	-0.019	-0.345	0.174	-0.222	-0.321	0.378	0.379	-0.323	0.323
37	Stem colour	-0.141	-0.207	0.161	0.070	0.891**	0.519**	0.555**	0.121	0.164	0.352*	0.318	0.070	-0.389*	0.490**	0.165	0.305	-0.321	-0.418	0.316	-0.032	-0.032
38	Seed colour	0.258	0.006	0.266	0.311	-0.372*	-0.677**	-0.564**	-0.153	-0.238	-0.790**	-0.047	0.416*	0.469**	-0.793**	-0.395*	-0.285	0.378*	-0.418*	-0.027	-0.141	-0.141
39	Stem pubescence density	0.154	-0.101	0.087	-0.060	0.271	0.529**	0.206	0.563**	0.502**	0.016	0.168	0.102	-0.060	0.161	0.280	0.229	0.379*	0.316	-0.027	-0.098	-0.098
40	1000 seed weight (g)	-0.359	-0.012	0.025	0.150	-0.008	0.130	0.242	0.125	0.158	0.027	0.004	0.005	0.004	0.198	0.039	0.104	-0.323	-0.032	-0.141	-0.098	-0.098

a = Annular constriction at the junction of calyx and peduncle; * = significant at 5%; ** = Significant at 1%

Table 3. Matrix of eigenvectors and values of the principal components for 40 morphological characters of chilli

Characters	Principal components							
	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈
Cotyledonous leaf length (mm)	<u>0.980</u>	-0.027	-0.12	0.003	-0.087	-0.075	0.017	-0.006
Cotyledonous leaf width (mm)	<u>0.821</u>	0.315	-0.023	0.076	-0.037	-0.352	-0.077	-0.071
Cotyledonous leaf colour	<u>0.932</u>	-0.025	0.146	0.085	-0.026	-0.183	0.113	0.010
Cotyledonous leaf shape	<u>0.890</u>	-0.196	-0.175	-0.212	-0.164	0.133	-0.036	0.119
Hypocotyl colour	<u>0.657</u>	-0.036	0.441	<u>0.553</u>	0.176	0.032	0.008	0.057
Hypocotyl pubescence	<u>0.743</u>	-0.223	0.193	-0.289	0.287	-0.162	-0.027	0.012
Plant growth habit	0.383	-0.414	0.495	-0.273	0.066	-0.097	0.171	0.248
Plant height	0.392	-0.113	<u>0.744</u>	0.259	0.197	0.063	0.064	0.187
Leaf pubescence density	0.179	0.010	<u>0.527</u>	<u>-0.596</u>	0.138	0.304	0.099	-0.407
Leaf pubescence type	0.253	0.022	<u>0.507</u>	<u>-0.628</u>	0.139	0.258	0.037	-0.324
Leaf shape	<u>0.757</u>	-0.357	-0.311	0.033	-0.049	0.297	0.005	-0.120
Leaf colour	<u>0.716</u>	0.188	0.254	0.002	0.209	0.223	-0.145	0.171
Branching habit	0.237	0.455	0.354	-0.09	0.556	0.116	-0.300	0.204
Mature leaf length	0.128	<u>0.509</u>	0.472	-0.025	-0.285	0.273	0.238	0.431
Mature leaf width	-0.296	<u>0.613</u>	0.478	0.095	-0.231	0.061	0.360	0.212
Stem colour	<u>0.682</u>	-0.03	<u>0.530</u>	0.392	-0.080	-0.160	-0.062	-0.014
Stem pubescence density	0.110	-0.256	<u>0.685</u>	-0.236	0.233	-0.053	0.282	-0.174
Number of pedicels/axil	-0.488	<u>0.645</u>	-0.107	0.150	-0.311	0.099	0.149	-0.219
Pedicel position at anthesis	<u>-0.545</u>	<u>-0.519</u>	0.330	-0.306	0.179	-0.148	-0.103	0.246
Angle between flower and pedicel	<u>-0.519</u>	<u>-0.584</u>	0.340	-0.221	0.083	-0.119	0.078	0.305
Corolla length	0.101	0.112	<u>0.576</u>	<u>0.723</u>	0.220	-0.154	-0.043	-0.134
Corolla colour	<u>0.854</u>	0.090	-0.067	0.268	-0.301	-0.021	0.077	0.035
Anther colour	<u>0.956</u>	-0.138	0.126	0.157	-0.048	0.045	-0.069	0.030
Calyx margin shape	<u>0.857</u>	0.182	-0.112	-0.198	-0.239	0.305	-0.051	0.078
Annular constriction*	<u>-0.542</u>	<u>0.642</u>	0.253	0.040	0.060	0.169	0.039	-0.103
Fruit position	-0.204	<u>-0.546</u>	0.241	0.027	-0.528	-0.027	0.142	-0.187
Fruit/plant	-0.368	<u>-0.809</u>	0.009	0.137	0.221	-0.190	0.078	0.072
Immature fruit colour	<u>0.655</u>	-0.037	0.476	<u>0.521</u>	0.130	-0.073	-0.037	-0.146
Mature fruit colour	0.035	0.109	<u>-0.533</u>	<u>0.677</u>	0.209	0.185	-0.145	-0.112
Fruit length	0.168	<u>0.670</u>	<u>-0.541</u>	-0.187	0.287	0.042	0.106	0.154
Fruit width	0.090	<u>0.888</u>	0.239	0.016	-0.04	-0.138	0.036	-0.056
Fresh fruit weight	0.156	<u>0.790</u>	-0.254	-0.127	0.238	-0.346	0.134	0.002
Dry fruit weight	0.377	<u>0.670</u>	-0.329	-0.228	0.273	-0.276	0.149	-0.031
Fruit shape	-0.096	<u>0.522</u>	<u>0.568</u>	-0.088	-0.068	-0.245	-0.213	0.008
Fruit cross-sectional corrugation	<u>-0.596</u>	<u>0.703</u>	0.112	0.049	0.094	0.110	-0.178	-0.008
Fruit pungency	<u>-0.757</u>	-0.072	0.279	0.346	0.268	0.247	-0.198	0.021
Fruit persistence	-0.027	-0.257	-0.351	0.406	0.449	0.522	0.261	-0.089
Seed colour	<u>-0.890</u>	0.196	0.175	0.212	0.164	-0.133	0.036	-0.119
No. of seeds/fruit	<u>0.872</u>	-0.020	0.042	-0.172	0.035	-0.049	-0.061	-0.161
1000 seed weight (g)	0.225	0.371	-0.219	-0.253	0.280	-0.050	0.179	-0.109
Total variance	13.234	6.813	4.739	3.677	2.063	1.849	1.767	1.137
% total contribution	33.086	17.033	11.848	9.193	5.157	4.622	4.418	2.842
Commulative %	33.086	50.119	61.967	71.160	76.317	80.939	85.358	88.199

* Annular constriction at the junction of calyx and peduncle

of all the seedling characters to the first PC indicated their large contribution towards the total variability of the population.

Majority of these characters in the first PC are qualitative in nature and most of them are determined by one or few genes and have a discrete distribution.

They can be easily identified and are little affected by environments, although, sometimes their expression may be altered by the action of modifying genes.

The second PC accounted for 17.03% of the total variability. This component was mainly linked with fruit characters as shown by its association with fruit width,

fresh and dry fruit weight, fruit length, fruit cross-sectional corrugation and fruit shape. The association of majority of the fruit characters to the second PC implied that fruit characters of chilli contribute considerably towards the variability and hence emphasis should be given to various fruit characters during germplasm characterization. Infact, the fruit character is so variable that the horticultural classification of chilli is solely based on it.

Plant height, stem pubescence density, corolla length, fruit shape, stem colour, leaf pubescence density and leaf pubescence type showed the greatest variability in third PC. Likewise, mature fruit colour, hypocotyl colour and immature fruit colour exhibited greater influence in fourth PC.

The vegetative characters were found to be distributed mostly in the first four PCs and their general lack of association among themselves and with most of the other plant characters except seedling characters indicated that they were independent set of characters. Therefore, in variability study, inclusion of as much as vegetative traits is important for correct assessment of variability. The inflorescence characters were mostly associated with the first and second PC indicating their significant contribution towards the total variability of the chilli cultivars.

The scatter plot of the cultivar drawn on the basis of the first two principal components is presented in Fig. 1. The differences in morphological characters contributing highly to the first PC (plotted in x-axis) which consisted mainly of seedling characters along with some vegetative, inflorescence and few fruit characters had clearly separated the *C. annuum* accessions from the *C. frutescens* and *C. chinense* accessions. On the other hand, characters contributing highly to the second PC (plotted in y-axis) consisted mainly of fruit characters

had distinctly separated most of the *C. frutescens* and *C. chinense* accessions.

The scatter plot technique also allowed distinct grouping of the accessions belonging to each of the species. Three groups were observed in *C. annuum* accessions. Group I included the accessions having purple colouration either in the whole plant or in parts of the plant indicating that this group was distinct from the other groups of *C. annuum*. Group II included *C. annuum* accessions with white flower, conical and elongate medium sized fruits, while group III comprised of accessions with long pendent fruits. Group IV represented the *C. chinense* accessions with relatively smaller erect fruits. The *C. frutescens* accessions belonging to group VI were characterized by small and erect fruit except for accessions ACC (F)-29 which had fruits comparable to accessions belonging to group V. However, two *C. annuum* accessions viz., ACC(A)-02 and ACC(A)-16 were placed outside the groups of the *C. annuum* accessions primarily because of their fruit characteristics which were markedly different from the other cultivars of *C. annuum*.

The characters discussed above not only appeared to be important for characterization of chilli germplasm due to their high contribution towards the variability but were also equally capable of resolving the cultivars into species level. Therefore, special emphasis should be given on these characters during morphological characterization of chilli germplasm.

Twenty eight, minimum descriptors were identified in this study based on principal component analysis and correlation among different characters. For integrating the list of minimum descriptors (Table 4), all the seedling characters except cotyledonous leaf width were retained as they not only contributed highly to the total variability

Table 4. Minimum descriptors for morphological characterization of chilli germplasm

Seedling characters	Inflorescence and fruit characters	Seed characters
Cotyledonous leaf length (mm)	Number of pedicels/axil	Seed colour
Cotyledonous leaf shape	Pedicel position at anthesis	No. of seeds/fruit
Cotyledonous leaf colour	Angle between flower and pedicel	
Hypocotyl pubescence	Corolla colour	
Hypocotyl colour	Calyx margin shape	
	Annular constriction at the junction of calyx and peduncle	
Vegetative characters	Fruit position	
Plant growth habit	Fruit/plant	
Plant height	Mature fruit colour	
Mature leaf length	Fruit length	
Leaf shape	Dry fruit weight	
Leaf colour	Fruit shape	
Branching habit	Fruit cross-sectional corrugation	
	Fruit pungency	
	Fruit persistence	

but some of them also showed significant association among themselves and with some other important traits. Cotyledonous leaf breadth was highly correlated with cotyledonous leaf length. Hence, scoring one of them would be sufficient. Similarly, leaf pubescences density, leaf pubescence type and stem pubescence density were also dropped from the list owing to their relatively low contribution towards total variability and their significant positive correlation with hypocotyl pubescence. Pubescence in hypocotyl is easier to score so retention of this character was felt sufficient.

Among the inflorescence characters, anther colour was omitted in the minimum descriptor list as it exhibited significant positive correlation with all the seedling characters and few other traits. Corolla length was rejected due to its non significant contribution to total variability.

The fruit characters of chilli are most important as some of them like fruit per plant, dry fruit weight, fruit shape and size, fruit colour and pungency, ultimately determine the economic value of the crop. Some of these characters like fruits per plant, fruit dry weight, fruit size etc. were found to be associated with fruit yield (Legg and Lippert, 1966; Gill *et al.*, 1977; Venkata Rao and Chhonkar, 1983). In the present study, dry and fresh fruit weight was found to be correlated and they contributed highly to the total variability. However, because of commercial importance and its correlation with fruits per plant and yield (Devi and Arumugam, 1999), dry fruit was retained. Among the seed characters, 1000 seed weight was rejected due to its low contribution to the total variability.

In the minimum descriptor list, some characters were however retained irrespective of their contribution to the total variability and correlation pattern primarily because these are considered species diagnostic traits. Moreover, many of the traits (pungency, fruit position, fruit shape, fruit colour, number of pedicels/axil, flower colour, leaf pubescence, plant colour, plant height etc.) included in the minimum descriptors are controlled by single or few genes (Legg and Lippert, 1966; Uzo, 1984; Loaiza-Figueroa and Tanksley, 1988; Shuh and Fontenot, 1990). Therefore, they are little effected by environment and can easily be identified. Thus, the set of minimum descriptors were supposed to be highly discriminating and expected to cover an important part of the existing diversity of chilli.

The Principal Component Analysis (PCA) allowed

the dissection of various morphological characters contributing highly to the total variability in chilli and thus provided a direction towards the choice of characters in variability study and characterization of chilli germplasm. It also provided a quicker method for morphological based classification of various species of chilli which is often necessary for initial categorization of germplasm. Twenty eight characters comprising of seedling, vegetative, inflorescence and fruit characters have been included in the list of minimum descriptors for chilli. These descriptors have high heritability, uniform expressivity and high visual scorability and thus expected to be highly discriminating and would allow rapid characterization of chilli germplasm.

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Variability and Association Studies for Stover Yield in Sorghum [*Sorghum bicolor* (L.) Moench]

Lata Chaudhary, Sheeshram and Lakshyadeep

Department of Plant Breeding & Genetics, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur-313 001 (Rajasthan)

Variability and path coefficient analysis were carried out in 130 germplasm lines of sorghum for stover yield and its components. The study revealed high estimates of PCV, GCV, heritability and genetic gain for number of leaves per plant and high estimates of PCV, GCV and moderate values of heritability and genetic gain were observed for panicle length. Stover yield exhibited positive and significant correlation with days to flowering, plant height, stem girth and green fodder yield per plot. Characters like plant height and stem girth, revealed high and positive direct effects on stover yield in path coefficient analysis. Germplasm lines Raj-20 and Raj-119 were found superior on the basis of per se performance.

Key words: Germplasm, Sorghum, Variability

Sorghum [*Sorghum bicolor* (L.) Moench] is a widely grown fodder crop in Rajasthan. Variability study for various yield-contributing characters is important for crop improvement. An attempt was made to access sorghum germplasm lines collected from various ecogeographic regions for evaluating genetic variability in some agromorphological traits.

Materials and Methods

The experimental material included 130 germplasm lines collected from different sorghum-growing districts of Rajasthan and five checks (SU-45, CSV-10, SU-52, CSV-15, and CSH-6). The experiment was carried out in augmented randomized block design with 10 blocks at the experimental fields of Rajasthan College of Agriculture, Udaipur. The lines were sown in 5m row length with spacing of 45 cm x 15 cm. Observations were recorded on five randomly selected plants for the traits viz. plant height (cm), panicle length (cm), number of leaves, leaf

length (cm), leaf width (cm), stem girth (mm), 1000-grain weight (g), green fodder yield per plot (kg) and stover yield per plot (kg). For days to 50 % flowering and days to maturity observations were recorded on complete plot basis. The plot means were used for analysis of variance and later on variability parameters, correlation and path coefficients were calculated.

Results and Discussion

Analysis of variance indicated that mean squares due to germplasm were significant for all the traits suggesting that experimental material possessed considerable variability. High magnitude of variation in the experimental material was also reflected by wider range for majority of traits. (Table 1).

For all the characters phenotypic coefficient of variation (PCV) was greater than genotypic coefficient of variation (GCV) indicating effect of environment on the expression of characters. However, trend of GCV

Table 1. Range of mean performance of germplasm lines and checks in sorghum

Character	Germplasm lines		Checks		CV (%)
	Range	GM	Range	GM	
Days to flowering	40.40-78.00	57.08	50.60-78.1	63.20	2.47
Days to maturity	83.00-304.70	95.11	84.80-112.40	97.10	7.32
Plant height	111.82-337.22	249.82	200.40-300.60	255.56	6.96
Panicle length	9.16-37.36	17.51	19-26.20	21.96	9.00
No. of leaves/plant	5.74-18.64	12.18	10.30-14.40	12.54	10.85
Leaf length	10.96-112.76	79.68	71.70-100.00	86.16	5.01
Leaf width	3.92-10.62	6.92	7.16-8.62	7.92	7.86
Stem girth	24.36-74.56	41.88	46.10-53.80	49.56	10.23
1000-grain weight	15.58-38.08	24.82	22.11-29.67	26.23	3.57
Green fodder yield	0.74-28.54	14.53	6.00-23.60	15.34	22.29
Dry fodder yield	0.87-16.80	6.04	2.09-7.18	4.87	25.90

and PCV was same. High estimates of PCV and GCV were observed for number of leaves per plant (59.69, 58.64) while for stover yield per plot (44.05, 41.23), green fodder yield per plot (41.23, 33.85) and panicle length (35.44, 33.59) estimates of PCV and GCV were moderate. High GCV for fodder yield was also reported by Patel *et al.* (1980). Heritability was high for days to flowering (98.24), number of leaves per plant (96.49), 1000-grain weight (93.62), days to maturity (91.13), leaf length (90.5) and plant height (90.11), while moderate

values were observed for panicle length (89.85), stem girth (82.72) and leaf width (82.59). Similar findings were reported by Nimbalkar (1987). The estimates of genetic gain revealed highest value for number of leaves per plant (118.66), whereas moderate values were obtained for dry fodder yield per plot (70.35), panicle length (65.60) and green fodder yield (57.25) (Table 2). The trait number of leaves per plant exhibited higher estimates of PCV, GCV, heritability and genetic gain; and panicle length showed high estimates of PCV, GCV and moderate values of heritability and genetic gain. Therefore selection is amicable for these traits.

The genotypic and phenotypic correlation coefficient showed similar trend (Table 3). Stover yield exhibited positive and significant correlation with days to flowering, plant height, stem girth and green fodder yield per plot at both genotypic and phenotypic levels, while with leaf length the correlation was positive and significant only at genotypic level. Henry *et al.* (1983) also reported similar findings for plant height and leaf length. The mutual association between these traits viz. days to flowering, plant height, leaf length, stem girth and green fodder yield per plot was positive and significant except of plant

Table 2. Variability parameters for various traits in sorghum

Character	PCV	GCV	H ²	GG
Days to 50% flowering	20.64	20.46	98.24	41.78
Days to maturity	25.08	23.95	91.13	47.09
Plant height (cm)	22.64	21.49	90.11	42.02
Panicle length (cm)	35.44	33.59	89.85	65.60
Number of leaves/plant	59.69	58.64	96.49	118.66
Leaf length (cm)	17.58	16.72	90.50	32.77
Leaf width (cm)	21.56	19.60	82.59	36.69
Stem girth (mm)	29.14	26.50	82.72	49.65
1000-grain weight (g)	14.96	14.48	93.62	28.86
Green fodder yield/plot (kg)	41.23	33.85	67.41	57.25
Dry fodder yield/plot (kg)	44.05	38.79	77.53	70.35

Table 3. Genotypic and phenotypic correlation coefficients between various traits in sorghum

S.No.	Character	r	Days to maturity	Plant height (cm)	Panicle length (cm)	Number of leaves/plant	Leaf length (cm)	Leaf width (cm)	Stem girth (mm)	1000-grain weight (g)	Green fodder yield/plot (kg)	Dry fodder yield/plot (kg)
1.	Days to 50% flowering	g	0.392	0.573*	-0.022	0.431	0.660**	0.663**	0.876**	0.496*	0.961**	0.670**
		p	0.369	0.541*	-0.023	0.415	0.612**	0.589*	0.781**	0.479*	0.757**	0.576*
2.	Days to maturity	g		-0.079	-0.089	0.851**	-0.186	0.231	0.310	0.080	0.359	0.162
		p		-0.085	-0.068	0.786**	-0.159	0.191	0.234	0.067	0.304	0.142
3.	Plant height (cm)	g			0.093	-0.092	0.711**	0.212	0.405	0.244	0.758**	0.659**
		p			0.082	-0.070	0.657**	0.189	0.360	0.210	0.557*	0.521*
4.	Panicle length (cm)	g				0.007	0.113	0.218	0.102	0.112	-0.092	-0.141
		p				-0.012	0.095	0.219	0.117	0.092	-0.055	-0.113
5.	Number of leaves/plant	g					-0.129	0.315	0.361	0.111	0.428	0.308
		p					-0.128	0.298	0.349	0.093	0.368	0.292
6.	Leaf length (cm)	g						0.523*	0.705**	0.313	0.637**	0.533*
		p						0.448	0.593**	0.295	0.518*	0.438
7.	Leaf width (cm)	g							0.837**	0.434	0.547*	0.319
		p							0.813**	0.389	0.419	0.298
8.	Stem girth (mm)	g								0.493*	0.793**	0.551*
		p								0.447	0.589*	0.476*
9.	1000-grain weight (g)	g									0.422	0.349
		p									0.304	0.278
10.	Green fodder yield/plot (kg)	g										0.823
		p										0.810

*, ** significant at 5% and 1% level of significance

Table 4. Path analysis indicating direct and indirect effects of various components on Stover yield in sorghum

S.No.	Character	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle length (cm)	Number of leaves/plant	Leaf length (cm)	Leaf width (cm)	Stem girth (mm)	Test weight (g)	Green fodder yield/plot (g)	r
1.	Days to 50% flowering	0.0704	-0.2260	0.4759	0.0063	0.3276	-0.1749	-0.1550	0.5590	0.0437	-0.2567	0.67
2.	Days to maturity	0.0276	-0.5769	-0.0656	0.0260	0.6467	0.0493	-0.0541	0.1982	0.0071	-0.0959	0.16
3.	Plant height (cm)	0.0403	0.0456	0.8306	-0.0271	-0.0695	-0.1885	-0.0496	0.2583	0.0215	-0.2025	0.66
4.	Panicle length (cm)	-0.0015	0.0513	0.0772	-0.2919	0.0056	-0.0301	-0.0510	0.0648	0.0098	0.0246	-0.14
5.	Number of leaves/plant	0.0304	-0.4910	-0.0760	-0.0021	0.7598	0.0343	-0.0737	0.2305	0.0098	-0.1143	0.31
6.	Leaf length (cm)	0.0465	0.1074	0.5908	-0.0331	-0.0983	-0.2650	-0.1222	0.4499	0.0275	-0.1700	0.53
7.	Leaf width (cm)	0.0467	-0.1335	0.1761	-0.0636	0.2394	-0.1385	-0.2338	0.5340	0.0383	-0.1460	0.32
8.	Stem girth (mm)	0.0616	-0.1791	0.3360	-0.0296	0.2743	-0.1868	-0.1956	0.6384	0.0435	-0.2119	0.56
9.	1000-grain weight (g)	0.0349	-0.0464	0.2030	-0.0326	0.0846	-0.0828	-0.1015	0.3148	0.0881	-0.1128	0.35
10.	Green fodder yield/plot (kg)	0.0677	-0.2070	0.6299	0.0269	0.3251	-0.1687	-0.1278	0.5064	0.0372	-0.2671	0.82

Res. effect: 0.5268

height with stem girth. Patel *et al.* (1973) also reported correlation between green fodder yield and plant height. So, simultaneous selection for these traits will help in improving the dry fodder yield.

Path coefficient analysis (Table 4) showed that out of five traits that exhibited significant positive correlation with stover yield per plot, only two traits, plant height and stem girth, revealed high and positive direct effects. The positive correlation of days to 50% flowering and green fodder yield per plot with stover yield was mainly due to indirect effects via stem girth whereas positive correlation of leaf length with stover yield per plot was chiefly contributed by indirect effect of plant height.

On the basis of mean performance, germplasm line Raj-20 was found superior as it exhibited high performance for Stover yield per plot (16.80 kg), green fodder yield per plot (26.54 kg), number of leaves per plant (17.74), leaf length (100.16 cm) and leaf width (8.30 cm). Other promising germplasm line was Raj-119 that expressed

high values for leaf width (10.62 cm), stem girth (74.56 mm) and green fodder yield per plot (26.14 kg).

On the basis of this investigation it can be concluded that direct selection is most effective for plant height and stem girth while indirect selection can be practiced for leaf length and green fodder yield per plot. Further, germplasm lines Raj-20 and Raj-119 could be utilized in future breeding programmes.

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Genetic Variability and Character Association in Muskmelon (*Cucumis melo* L.)

Sudhakar Pandey, Mathura Rai and B Singh

Indian Institute of Vegetable Research, Banaras Hindu University, Varanasi-221 005 (Uttar Pradesh)

Genetic variability, heritability (h^2), genetic advance, character association and path analyses were carried out in 35 accession of muskmelon (*Cucumis melo* L.). The observations were recorded on 13 characters. The high phenotypic (PCV) and genotypic (GCV) coefficient of variation was observed high for yield and fruit weight, while, the lowest phenotypic and genotypic coefficient of variation were observed for number of days to first female flower anthesis followed by number of day to 50% male flower anthesis and number of days to 50% female flower anthesis. High heritability along with high expected genetic advance were recorded for number of days to 50% female flower anthesis, TSS and number of days to first male flower anthesis. Yield has positive and significant correlation with fruit weight, fruit diameter, length, flesh thickness and rind thickness at both phenotypic and genotypic level. The fruit weight, fruit diameter, length, flesh thickness and rind thickness had positive correlation coefficient among themselves. Higher and positive direct effect on yield was exerted by fruit diameter followed by number of fruits, fruit weight and rind thickness. Direct selection based on fruit diameter and fruit weight results in an appreciable improvement for total yield. Besides direct selection for fruit yield, indirect selection through the fruit length and number of fruits should be considered for further improvement of yield.

Key words: *Cucumis melo*, Variability, Correlation, Path analysis

Muskmelon (*Cucumis melo* L.) belong to family cucurbitaceae is used as desert fruit and vegetable in variety of ways. Muskmelon is rich in quality and nutritive value. Evaluation of the available variability is prerequisite for planning the value added improvement programme. The germplasm, which maintain in heterogeneous environment may be genetically diverse and can provide a plenty of scope for screening the better genotype with specific traits. Knowledge on the nature and magnitude of variation provide a rational choice of character(s) on which selection can be exercised. The observed variability is a combined estimate of genetic and environmental factors, of which only former one is heritable. However the estimate of heritability alone does not provide an idea about the expected gain in next generation, therefore it has been considered in conjunction with genetic advance. Correlation and path analysis establish the extent of association between yield and its components and also bring out relative importance of their direct and indirect effects. This gives a clear understanding of their association with yield. Hence, the present study was carried out to assess the performance of various economic traits and to measure the extent of variability, heritability, expected genetic advance and interrelationship of yield components in muskmelon.

Materials and Methods

Thirty-five accessions of muskmelon were grown in Completely Randomized Blocks Design with three replications with row-to-row distance of 1.5 m and plant-

to-plant distance of 40 cm during summer, 2001. Eight plants were maintained in each plot. All the cultural practices and fertilizers were given as per recommendations for proper growth and stand of the crop as and when required. The observations were recorded on five competitive plants for each treatment in each replication selected at random for number of days taken to first male flower anthesis, number of days taken to 50% male flower anthesis, number of days taken to first female flower anthesis, number of days taken to 50% female flower anthesis, number of node at which first female flower appears, number of fruits per plant, average fruit weight (kg), fruit diameter (cm), fruit length (cm), flesh thickness (cm), rind thickness (cm), total soluble solids (%) and yield per plant (kg). Data were averaged and analysed for standard statistical procedure followed for estimating the genotypic and phenotypic coefficient of variation (Burton, 1952), heritability (Hanson *et al.*, 1956) and genetic advance (Johnson *et al.*, 1955). Phenotypic and genotypic correlation coefficients were calculated following Al-Jibouri *et al.*, (1958) and path analysis following the method of Dewey and Lu (1959).

Results and Discussion

The mean performance of genotypes (Table I) indicated widest range for number of days to first 50% female flower anthesis (43.33-56.00) followed by number of days to 50% male flower anthesis (40.00-52.00) and number of days to first male flower anthesis, while the narrowest range was observed for rind thickness (0.02-0.04) followed by average fruit weight (0.15-0.70)

Email: sudhakariivr@yahoo.com, sudhakar@iivr.org

and yield per plant (0.25-1.49). The analysis of variance indicated highly significant variation among the genotypes for all characters (Table 2). This variability may be due to genetic constitution of the materials as well as environmental influences. The estimates of mean, range,

phenotypic (PCV) and genotypic (GCV) coefficient of variation, heritability (h^2) and genetic advance is presented in table 3. Maximum mean value (43.33-56.00) was observed for number of days to 50% female flower anthesis with an average of 46.78. The minimum range

Table 1. Mean values of the 35 genotypes

Variety	Number of days to first male flower anthesis	Number of days to 50% male flower anthesis	Number of days to first female flower anthesis	Number of days to 50% female flower anthesis	No. of node at which first female flower appear	No. of fruits per plant	Average fruit weight (kg)	Fruit diameter (cm)	Fruit length (cm)	Flesh thickness (cm)	Rind thickness (cm)	T.S.S. (%)	Yield per plant (kg)
VRM-5C	42.00	45.67	48.00	53.00	3.33	1.30	0.20	8.00	8.00	1.50	.20	6.20	0.26
MH-16-2	38.00	42.00	41.67	51.00	8.00	3.50	0.30	8.50	8.50	2.10	.20	5.17	0.80
VRM-17B	38.00	45.00	48.00	51.00	5.33	2.00	0.65	12.00	9.00	3.10	.20	7.17	1.30
MH-61-4	46.00	42.67	41.67	50.33	4.17	1.60	0.51	9.0	7.50	1.50	.20	3.73	1.17
MH-13A	38.00	41.00	47.00	49.33	3.67	2.00	0.70	10.5	9.00	2.50	.20	7.53	1.40
MH-14	38.00	41.67	46.00	49.67	7.33	1.30	0.52	10.0	8.00	2.00	.31	8.83	0.69
MH-2-1	39.67	44.00	46.00	46.00	6.00	2.00	0.42	9.0	8.50	3.00	.40	6.13	0.97
MH-2-4	42.67	46.00	50.00	46.00	5.00	2.00	0.32	7.0	7.50	1.50	.20	6.97	0.64
MH-5	38.00	48.00	44.00	49.67	7.50	2.00	0.25	5.5	5.20	1.50	.15	6.50	0.59
MH-5A	37.67	41.00	45.00	52.67	4.00	2.60	0.40	9.33	8.50	2.00	.21	8.00	1.03
MH-61(2)	39.00	46.00	44.33	49.00	5.13	2.80	0.60	11.0	10.50	2.53	.33	7.33	1.49
VRM-12	37.33	40.67	47.67	47.00	2.93	2.00	0.22	7.0	7.50	1.50	.11	5.00	0.43
VRM-17B-1	37.00	52.00	48.67	51.00	5.40	2.30	0.35	7.33	7.33	1.87	.21	5.00	1.10
VRM-20	38.00	44.00	46.00	43.33	4.50	2.30	0.20	7.0	6.00	1.50	.12	8.00	0.57
VRM-20-1	39.00	40.00	49.33	53.00	5.50	1.60	0.30	8.0	8.00	2.60	.20	5.17	0.60
VRM-32(1)	37.00	43.00	48.00	55.00	5.27	2.30	0.16	7.0	6.00	1.60	.15	5.50	0.6
VRM-32(2)	35.67	42.67	46.00	54.00	5.33	2.00	0.25	7.9	7.07	1.80	.20	4.00	0.50
VRM-32A	37.00	43.00	50.67	53.67	4.33	2.30	0.25	7.50	8.00	1.50	.02	6.33	0.61
MJ-1	37.33	42.00	47.00	54.00	5.00	2.00	0.30	10.0	8.00	1.560	.20	7.20	1.37
MJ-4	45.00	46.00	50.00	56.00	8.00	1.30	0.50	10.5	7.27	2.50	.14	8.40	0.63
MJ-8	38.00	42.00	46.00	53.00	5.67	2.30	0.20	8.0	7.00	1.50	.10	8.33	0.45
MJ-12	41.67	46.00	48.33	51.00	5.17	2.60	0.30	8.77	7.50	1.50	.14	7.00	0.76
MJ-25	38.00	42.00	47.67	53.00	5.17	2.30	0.20	6.5	6.00	1.50	.20	9.00	0.51
MJ-26	43.00	46.00	46.00	49.00	6.00	2.30	0.45	10.0	8.50	2.40	.20	7.50	1.11
MJ-31	47.00	48.00	50.00	56.00	5.83	2.00	0.37	9.5	6.00	2.10	.12	6.00	1.32
MM-1	38.00	42.00	46.00	48.33	4.50	2.80	0.38	8.0	7.00	2.00	.20	8.00	1.05
MM-4	38.00	41.67	46.00	48.00	4.00	3.83	0.45	9.0	10.00	2.50	.20	6.00	1.40
MM-7	42.00	46.00	45.00	50.00	3.67	3.40	0.15	6.0	5.50	1.50	.15	5.00	0.62
MM-10	43.00	46.00	47.00	51.00	3.83	2.53	0.18	7.0	6.00	1.50	.14	7.50	0.38
MM-20	39.00	44.00	46.00	50.33	4.00	3.00	0.20	7.47	6.50	1.80	.11	9.00	0.55
MM-25	42.00	46.00	45.33	51.33	5.50	1.50	0.18	6.00	6.00	1.50	.12	8.83	1.25
Bihar	42.00	45.00	46.00	47.00	4.33	1.30	0.62	11.50	9.00	2.50	.20	7.13	0.93
GZB-2	37.00	42.00	46.00	51.00	3.17	2.37	0.21	6.0	10.00	2.00	.20	8.07	0.57
Arkajeet	42.00	45.00	49.00	52.00	4.00	2.60	0.40	7.13	6.50	1.50	.14	8.00	1.28
Indira	37.00	42.00	48.00	52.00	4.67	2.60	0.50	9.00	8.50	2.00	.13	10.00	1.40
SEM	1.31	4.56	1.27	1.30	0.88	0.51	0.02	0.88	0.58	0.28	.01	0.48	0.22
C.D. at 5%	2.58	3.07	2.50	2.55	1.72	1.00	0.05	1.72	1.13	0.54	.03	0.95	0.43

Table 2. Analysis of variance

Source of Variance	d.f	Number of days to first male flower anthesis	Number of days to 50% male flower anthesis	Number of days to first female flower anthesis	Number of days to 50% female flower anthesis	No. of node at which first female flower appear	No. of fruits per plant	Average fruit weight (Kg)	Fruit diameter (cm)	Fruit length (cm)	Flesh thickness (cm)	Rind thickness (cm)	T.S.S. (%)	Yield per plant (Kg)
Replication	2	1.91	1.062	0.492	4.85	1.085	2.748	0.010	7.017	1.323	0.106	0.00303	1.267	0.293
Treatment	34	24.73**	20.027**	13.45**	36.0**	4.886**	1.124**	0.070**	8.275**	5.278**	0.692**	0.0141**	6.904**	0.4288**
Error	68	1.30	1.851	1.23	1.27	0.582	0.195	0.00062	0.582	0.251	0.057	0.00022	0.177	0.0361

* Significant at 5% probability level, ** Significant at 1% probability level.

Table 3. Range, mean, variability, heritability and genetic advance

Character	Range		Mean	Variability		Heritability	Genetic advance
	Min.	Max.		PCV	GCV		
No. of days to first male flower anthesis	35.67	47.0	39.66	7.61	7.05	85.70	5.33
No. of days to 50% male flower anthesis	40.00	52.00	43.97	6.40	5.60	76.60	4.44
No. of days to first female flower anthesis	41.67	50.67	46.78	4.92	4.31	76.80	3.64
No. of days to 50% female flower anthesis	43.33	56.00	50.79	7.08	6.72	90.10	6.65
No. of node at which first female flower appear	2.93	8.00	5.00	28.37	23.92	71.10	2.08
No. of fruits per plant	1.30	3.83	2.25	31.64	24.76	61.20	0.90
Average fruit weight (kg)	0.15	0.70	0.35	44.48	43.90	97.40	0.31
Fruit diameter (cm)	5.50	12.00	8.34	21.27	19.20	81.50	2.98
Fruit length (cm)	5.20	10.50	7.58	18.31	17.07	86.90	2.49
Flesh thickness (cm)	1.50	3.10	1.92	26.93	23.90	78.80	0.84
Rind thickness (cm)	0.02	0.40	0.18	38.79	37.88	95.40	0.14
TSS (%)	3.73	10.00	6.96	22.36	21.52	92.70	2.97
Yield per plant (kg)	0.25	1.49	0.83	49.14	43.49	78.40	0.66

of mean value (0.02-0.04 cm) with an average of 0.18 cm was recorded for rind thickness. High magnitude of phenotypic coefficient of variance than the genotypic values indicated considerable influence of environment on the expression of the characters. The maximum phenotypic coefficient of variation (PCV) was observed for yield, rind thickness, fruit weight and number of fruits, while the lowest phenotypic coefficient of variation were observed for number of days to first female flower anthesis followed by number of day to 50% male flower anthesis and number of days to 50% female flower anthesis. Moderate phenotypic coefficient of variation was exhibited by flesh thickness, TSS (total soluble solids) and fruit diameter. Similar results have been reported by Prasad and Prasad (1978a). Whereas, high genotypic coefficient of variation observed for yield, fruit weight and flesh thickness. The lowest value of genotypic coefficient of variation were observed for number of days to first female flower anthesis followed by number of day to 50% male flower anthesis and number of days to 50% female flower anthesis. These results are in conformity with the findings of Singh *et al.*, (1989). Average genotypic coefficient of variability recorded for number of fruits, flesh thickness and TSS.

Heritability values ranged from 61.20% to 97.40% for the characters under study. The highest heritability was noted for fruit weight, rind thickness, TSS and number of days to germination. The above estimates gave an indication that substantial genetic improvement can be achieved in this character (Kalloo *et al.*, 1983). The medium heritability was noted for fruit length and diameter, flesh thickness, number of days to first male flower anthesis and yield. Whereas, lowest heritability was noted for number of days to 50% male flower anthesis, number of days to first female flower anthesis, number of node

at which first male flower appears and fruits per plant (Prasad and Singh, 1992). The value of expected genetic advance was highest for number of days to 50% female flower anthesis, followed by number of days to first male flower anthesis and number of days to 50% male flower anthesis. However, low value of genetic advance was recorded for rind thickness, flesh thickness, fruit weight, yield and fruits per plant (Mangal *et al.*, 1981). High heritability along with high expected genetic advance were recorded for number of days 50% female flower anthesis, TSS and number of days to first male flower anthesis (Pandey *et al.*, 2002). The magnitude of high heritability coupled with moderately low genetic advance was observed for fruit weight, rind thickness, flesh thickness, fruit length, and yield, which may be due to dominance and inter-allelic interaction (Kalloo *et al.*, 1983).

Genotypic correlation coefficient was higher than their corresponding phenotypic correlation coefficient for most of the characters except number of days to first male flower anthesis, number of fruits and TSS (Table 4). A perusal of data revealed that yield has positive and significant correlation with fruit weight, fruit diameter and length, flesh thickness and rind thickness at both phenotypic and genotypic level. The fruit weight, fruit diameter and length, flesh thickness and rind thickness had positive correlation coefficient among themselves (Vijay, 1987). Higher and positive direct effect (at the genotypic level) on yield was exerted by fruit diameter followed by number of fruits, fruit weight and rind thickness (Table 5). All above discussed characters also showed positive correlation with yield. This indicated that direct selection based on fruit diameter and fruit weight results in an appreciable improvement for total yield. However, number of days to 50% male flower

Table 4. Estimates of genotypic and phenotypic correlation coefficients

Characters	Number of days to first male flower anthesis	Number of days to 50% male flower anthesis	Number of days to first female flower-anthesis	Number of days to 50% female flower-anthesis	Number of node at which first female-flower appear	Number of fruits per plant	Average fruit weight (Kg)	Fruit diameter (cm)	Fruit length (cm)	Flesh thickness (cm)	Rind thickness	T.S.S. (%)	Yield per plant
	1	2	3	4	5	6	7	8	9	10	11	12	13
1		0.450 0.352*	0.093 0.084	0.101 .093	0.079 0.060	-0.295 -0.243	0.127 0.124	0.146 0.141	-0.253 -0.199	-0.031 -0.016	-0.083 -0.049	-0.079 -0.054	0.056 0.016
2			0.225 0.178	-0.008 0.022	0.251 0.190	-0.077 -0.071	-0.049 -0.039	-0.110 -0.069	-0.321 -0.290*	-0.74 -0.058	-0.049 -0.043	-0.081 -0.051	0.003 0.017
3				0.303 0.271	-0.094 -0.101	-0.318 -0.201	-0.046 -0.54	0.015 0.064	-0.129 -0.076	-0.011 0.017	-0.356 -0.298*	0.167 0.120	-0.056 -0.066
4					0.215 0.162	-0.156 -0.086	-0.090 -0.103	0.063 0.230	-0.111 -0.070	-0.066 -0.065	-0.229 -0.196	-0.053 -0.043	-0.049 -0.015
5						-0.236 -0.122	0.144 0.136	0.149 -0.267	-0.121 -0.146	0.270 0.210	0.233 0.180	-0.060 0.040	-0.026 -0.027
6							-0.198 -0.147	-0.114 0.882**	0.069 0.637	-0.012 -0.082	-0.121 -0.075	0.040 -0.021	0.280 0.206
7								0.797 0.703**	0.580 0.656**	0.755 0.646**	0.456 0.438**	-0.030 0.127	0.799 .694**
8									0.556 0.496**	0.772 0.590**	0.403 0.375**	0.116 0.068	0.725 0.560
9										0.677 0.572**	0.498 0.452**	0.023 0.029*	0.523 .433**
10											0.591 0.493**	0.020 0.020	0.567 0.402*
11												-0.085 -0.085	0.340 0.308*
12													0.033 0.032

* Significant at 5% probability level, ** Significant at 1% probability level

Table 5. Direct (diagonal) and indirect effects of different traits on yield (Genotypic)

Characters	Number of days to first male flower anthesis	Number of days to 50% male flower anthesis	Number of days to first female flower-anthesis	Number of days to 50% female flower-anthesis	Number of node at which first female-flower appear	Number of fruits per plant	Average fruit weight (Kg)	Fruit diameter (cm)	Fruit length (cm)	Flesh thickness (cm)	Rind thickness	T.S.S. (%)	Genetic correlation coefficient with yield
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.046	-0.050	0.044	0.001	0.000	-0.260	0.083	0.146	0.045	0.026	-0.030	0.004	0.056
2	0.021	-0.111	0.107	0.000	0.001	-0.068	-0.032	-0.110	0.057	0.063	-0.018	0.004	0.003
3	0.004	-0.025	0.476	0.004	0.000	-0.280	-0.030	-0.002	0.023	0.010	-0.130	-0.009	-0.056
4	0.005	0.001	0.144	0.014	0.001	-0.137	-0.059	0.064	0.019	0.056	-0.084	0.003	-0.049
5	0.004	-0.028	-0.045	0.003	0.004	-0.208	0.094	0.231	0.021	-0.231	0.085	-0.002	-0.026
6	-0.014	0.009	-0.151	-0.002	-0.001	0.880	-0.129	-0.267	-0.012	0.010	-0.044	0.001	-0.280
7	0.006	0.005	-0.022	-0.001	0.001	-0.174	0.651	0.883	-0.112	-0.644	0.167	-0.007	0.799
8	0.007	0.012	-0.001	0.001	0.001	-0.235	0.575	1.001	-0.116	-0.659	0.148	-0.005	0.725
9	-0.012	0.036	-0.061	-0.002	-0.001	0.061	0.415	0.656	-0.176	-0.578	0.182	-0.001	0.560
10	-0.001	0.008	-0.005	-0.001	0.001	-0.010	0.492	0.773	-0.119	-0.853	0.216	-0.001	0.567
11	-0.004	0.005	-0.169	-0.003	0.001	-0.107	0.297	0.403	-0.088	-0.504	366	0.004	0.340
12	-0.004	0.009	0.080	-0.001	0.000	-0.019	0.083	0.105	-0.004	-0.017	-0.031	-0.052	0.033

* Significant at 5% probability level, ** Significant at 1% probability level. Genotypic residual effect = 0.0606

anthesis, fruit length, flesh thickness and TSS was exerted negative direct effect on yield. From the results of this investigation, it is concluded that besides direct selection for fruit yield, indirect selection through the fruit length and number of fruits per plant should be considered for further improvement of yield in muskmelon. Few genotypes MH-6I-2, MH-13A, MM-4, Indira, MJ-1, MJ-31, VRM-17B and Arka Jeet were found promising in order as for as yield and other above mentioned important yield contributing traits are concerned. Thus, by exploiting the above listed genotypes, there is good scope of improvement through selection in many of the economic traits by making judicious use of the available information gathered from the study.

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Studies on Biodiversity in Grain Cowpea [*Vigna unguiculata* (L.) Walp.]

Sunil K. Madheshia and Indra Deo Pandey*

Deptt. of Genetics and Plant Breeding, G.B. Pant University of Agriculture & Technology, Pantnagar (Uttaranchal)

Sixty five genotypes of grain cowpea (Source: International Institute of Tropical Agriculture, Nigeria) were evaluated for thirteen metric characters to observe the genetic diversity existing among them by Mahalanobis D² statistics. Out of sixty five, only sixty three genotypes responded towards flowering, on which further study was taken out. The analysis of variance revealed significant differences among the genotypes for each character under study. These sixty three genotypes were grouped into twenty four clusters and the maximum intra-cluster distance was observed in cluster VIII. The maximum inter cluster distance was recorded between cluster XVII and XXII. Based on the cluster means and cluster distances the genotypes EC 517122 (cluster X) and EC 517123 (cluster XXII) were found the most promising. Among the traits studied, days to first flowering and number of pods per plant contributed towards maximum divergence.

Key words: Cowpea, [*Vigna unguiculata* (L.) Walp.], Cluster, D² statistics, Genotypes, Divergence

Among legumes, cowpea is being grown in almost all parts of India except high hills. It is a unique pulse crop with manifold uses such as pulse (dal), green vegetables, green fodder and as a cover crop for stopping soil erosion. But due to low yield we are unable to exploit the crop efficiently. Therefore crop improvement programme is necessary to increase the productivity. For any crop improvement programme variability is the first requirement. For proper utilization of variability in breeding programme an efficient screening, evaluation and documentation of germplasm lines for useful traits is essential so that the potential value of particular germplasm line may be assessed. In present research programme, genetic diversity in a set of sixty three cowpea genotypes was assessed by Mahalanobis D² statistics for different traits.

Materials and Methods

Sixty five genotypes of grain cowpea (Source IITA, Nigeria) were evaluated in Randomized Block Design (R.B.D) in the 'zaid' season of 2005. The genotypes were

sown in two meter rows with 3 replications at spacing of 45x15 cm. Out of sixty five genotypes, only sixty three genotypes responded towards flowering. Therefore, data were recorded on sixty three genotypes. Observations were taken on 5 randomly selected plants in each of these 63 genotypes from each replication for 13 quantitative characters i.e. days to 1st flowering, days to 50% flowering, days to 1st pod maturity, days to maturity, plant height, number of primary branches per plant, number of secondary branches per plant, number of pods per plant, pod size, number of seeds per pod, 100 seed weight, seed yield per plant & green stover yield per plant. Analysis of variance was carried out for each trait & then multivariate analysis of Mahalanobis (1936). The genotypes were grouped into clusters by Tocher's method (Rao, 1952).

Results and Discussion

The analysis of variance (ANOVA) showed significant differences among the genotypes for all the thirteen traits studied (Table 1). On the basis of D² values, the different genotypes of grain cowpea were grouped into twenty

Table 1. Analysis of variance for 13 metric character in 63 cowpea genotypes

Source of variation	Degree of freedom	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀	X ₁₁	X ₁₂	X ₁₃
Treatment	62	195.45 **	213.4 **	189.3 **	213.3 **	7822.90 **	4.501 **	164.0 **	658.768 **	9.544 **	13.69 **	27.58 **	1354 **	115120 **
Error	124	0.896	1.836	0.865	0.842	1.198	0.327	0.944	0.46507	0.220	0.289	0.142	0.12	8.45
G.M.		55.857	65.55	74.40	85.17	97.82	4.566	18.0	24.671	13.9	11.22	17.73	30.4	280.2
S.Em.		0.5465	0.782	0.537	0.529	0.632	0.330	0.560	0.39373	0.271	0.310	0.068	0.20	1.679
C.V.		1.6947	2.067	1.250	1.077	1.119	12.52	5.372	2.7641	3.356	4.794	0.673	1.14	1.037

X₁= days to 1st flowering, X₂= days to 50% flowering, X₃= days to 1st pod maturity, X₄= days to maturity, X₅= plant height (cm), X₆= number of primary branches/ plant, X₇= number of secondary branches / plant, X₈= number of pods / plant, X₉= pod size (cm), X₁₀= number of seeds / pod, X₁₁= 100 seed weight (gm), X₁₂= seed yield/ plant (gm), X₁₃= Stover yield/plant (gm).

* Author for correspondance

four clusters. The cluster strength varied from single genotype (cluster IX-XXIV) to thirty genotypes (cluster I). The pattern of distribution of these germplasm lines into 24 clusters confirmed the existence of variability among the genotypes indicated by ANOVA. The average intra and inter cluster distances are given in Table 3. The intra-cluster distance ranged from 0.00 (cluster IX - XXIV) to 15.3 (cluster VIII). Maximum inter cluster distance (60.3) was recorded between cluster XVII & XXII showing maximum diversity followed by cluster XIX & XXI (59.9).

The average cluster mean for different characters (Table 4) exhibited that the cluster X had minimum days to 1st flowering & cluster XVII had minimum days to maturity. Cluster XXIII had maximum plant height whereas cluster IX had minimum plant height. Cluster V had maximum primary branches per plant and cluster

XVI had maximum secondary branches per plant. Cluster XXII had maximum number of pods per plant and cluster XVIII had maximum pod size. Cluster XVI had maximum number of seeds per pod. Cluster XXIV had maximum 100 seed weight. Cluster XXII had maximum seed yield per plant and green stover yield per plant.

As per earlier reports heterosis and better recombinants can be obtained by crossing between parents of clusters of high and low means (Usha Kumari *et al.*, 2000, Girish *et al.*, 2001). Therefore for getting better heterosis, the genotypes from cluster XXII and IX with high and low cluster means for majority of characters respectively can be used for hybridization programme for yield improvement in grain cowpea varieties.

In addition, the contribution of each character to genetic divergence was calculated. It was found that number of pods per plant contributed maximum towards

Table 2. Composition of genotypes in clusters

Cluster number	Number of genotypes included	Genotypes
Cluster I	30	EC-517112, EC-517114, EC-517115, EC-517117, EC-517120, EC-517124, EC-517128, EC-517133, EC-517134, EC-517138, EC-517139, EC-517141, EC-517144, EC-517149, EC-517150, EC-517151, EC-517152, EC-517153, EC-517154, Cowpea Black-2, EC-528689, EC-528694, EC-528695, EC-528696, EC-528697, EC-528698, EC-528699, EC-528700, EC-528701, EC-528703
Cluster II	3	EC-517130, EC-517136, EC-517146
Cluster III	2	EC-517125, Cowpea Black-1
Cluster IV	3	EC-517137, EC-528691, EC-528692
Cluster V	2	EC-517116, EC-517155
Cluster VI	3	EC-517147, EC-528602, EC-528693
Cluster VII	2	EC-517135, EC-517148
Cluster VIII	2	EC-517126, Com-1
Cluster IX	1	EC-517119
Cluster X	1	EC-517122
Cluster XI	1	EC-517129
Cluster XII	1	EC-517121
Cluster XIII	1	EC-517131
Cluster XIV	1	EC-517142
Cluster XV	1	EC-517113
Cluster XVI	1	EC-528690
Cluster XVII	1	EC-528687
Cluster XVIII	1	EC-517145
Cluster XIX	1	EC-517127
Cluster XX	1	EC-517132
Cluster XXI	1	EC-517118
Cluster XXII	1	EC-517123
Cluster XXIII	1	EC-517140
Cluster XXIV	1	EC-517143

Cluster No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV
	13.4	11.0	9.5	14.0	9.9	13.8	12.5	15.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	16.8	22.9	31.7	36.9	28.1	31.4	41.6	39.1	25.7	27.4	19.4	28.7	28.9	26.9	26.9	28.2	37.5	34.6	36.9	39.0	35.9	41.3	50.9	43.5
	22.0	22.9	33.2	25.7	26.0	28.5	23.9	29.2	38.5	33.8	25.6	36.6	31.7	34.9	34.2	36.6	42.8	40.8	35.7	43.4	44.1	55.1	55.5	55.1
	21.0	33.2	21.0	30.5	30.1	32.5	31.2	25.2	24.3	36.0	34.3	23.1	20.3	40.8	34.3	50.9	34.1	41.0	32.4	39.2	38.2	50.7	41.0	40.6
	24.4	25.7	24.4	36.9	28.1	30.5	31.2	25.2	24.3	36.0	34.3	23.1	20.3	40.8	34.3	50.9	34.1	41.0	32.4	39.2	38.2	50.7	41.0	40.6
	22.6	22.6	22.2	30.5	30.1	32.5	31.2	25.2	24.3	36.0	34.3	23.1	20.3	40.8	34.3	50.9	34.1	41.0	32.4	39.2	38.2	50.7	41.0	40.6
	22.2	22.2	22.2	30.5	30.1	32.5	31.2	25.2	24.3	36.0	34.3	23.1	20.3	40.8	34.3	50.9	34.1	41.0	32.4	39.2	38.2	50.7	41.0	40.6
	29.1	23.9	29.1	30.5	30.1	32.5	31.2	25.2	24.3	36.0	34.3	23.1	20.3	40.8	34.3	50.9	34.1	41.0	32.4	39.2	38.2	50.7	41.0	40.6
	19.5	18.3	28.8	23.0	28.8	28.8	23.0	29.2	31.1	29.3	36.2	28.7	19.0	36.2	30.9	31.0	34.1	41.0	32.4	39.2	38.2	50.7	41.0	40.6
	19.7	20.9	32.3	21.5	32.3	21.5	23.0	38.5	31.1	29.3	36.2	28.7	19.0	36.2	30.9	31.0	34.1	41.0	32.4	39.2	38.2	50.7	41.0	40.6
	19.9	21.3	18.3	34.9	18.3	34.9	32.6	36.9	27.4	19.4	28.7	28.7	28.9	26.9	26.9	28.2	37.5	34.6	36.9	39.0	35.9	41.3	50.9	43.5
	16.4	25.1	24.7	25.4	24.7	25.4	23.1	36.6	31.7	22.3	21.2	28.7	28.9	26.9	26.9	28.2	37.5	34.6	36.9	39.0	35.9	41.3	50.9	43.5
	17.6	22.7	26.0	34.8	26.0	34.8	20.3	30.3	31.7	22.3	21.2	28.7	28.9	26.9	26.9	28.2	37.5	34.6	36.9	39.0	35.9	41.3	50.9	43.5
	25.4	32.5	30.8	32.4	30.8	32.4	40.8	31.3	35.5	34.9	20.6	38.7	28.9	26.9	26.9	28.2	37.5	34.6	36.9	39.0	35.9	41.3	50.9	43.5
	28.1	33.0	23.0	27.1	23.0	27.1	34.5	42.4	26.1	34.2	20.6	38.7	28.9	26.9	26.9	28.2	37.5	34.6	36.9	39.0	35.9	41.3	50.9	43.5
	29.6	37.5	29.4	37.7	29.4	37.7	45.9	42.8	28.5	30.4	47.5													

Table 4. Cluster Means For 13 Characters of 63 Cowpea Genotypes

199	28.0	17.3	11.3	13.4	21.6	16.4	4.61	85.0	84.9	74.3	65.0	55.5	I
140	27.2	20.7	9.99	12.1	31.2	17.6	4.33	45.8	81.6	68.9	58.3	50.9	II
174	25.2	19.6	11.3	14.7	23.9	25.6	4.67	201	81.6	70.6	60.9	52.1	III
584	78.0	14.5	13.2	14.5	60.7	19.9	3.99	103	91.1	78.3	73.1	60.6	IV
187	26.6	20.4	7.16	12.2	19.6	22.6	8.99	44.8	77.8	68.4	59.3	50.3	V
207	14.4	13.2	5.67	10.3	34.1	15.3	4.21	63.1	80.5	70.2	61.0	51.1	VI
260	41.5	22.2	10.1	17.2	23.9	24.1	4.33	75.3	78.3	66.6	58.1	48.1	VII
377	25.0	17.8	12.4	15.2	41.3	9.9	3.33	76.9	89.9	81.3	71.1	60.8	VIII
56.3	11.3	17.6	11.3	12.6	13.6	24.3	4.67	39.6	77.3	62	57.6	50.3	IX
598	59.6	17.4	11.6	13.6	42.3	30.6	6.33	59.6	75.3	67.3	57	46.3	X
203	56.3	23.7	11.3	13.3	56.6	16.3	4.33	161	89.3	80.3	70.6	58.3	XI
97.6	15.6	18.2	12.6	13.6	13.6	10.3	4.67	84.6	75.3	69.2	51.6	51.6	XII
203	15.5	20	10.3	16.3	13.6	23.6	6.33	59.3	86.6	75.3	63	52	XIII
674	12.8	14.4	12	14.2	12.6	14.3	3.33	207	101	86.3	76	69.3	XIV
478	27.6	19.4	11.3	14.3	25.3	24.3	5.33	190	89.3	74	71	54.6	XV
200	31.7	13.7	15.3	19.3	26.3	40.6	4.33	90	80.6	70.6	61.3	53.3	XVI
449	11.6	12.8	13.6	11.6	9.67	15.3	3.67	214	72.6	62.6	53.3	46.6	XVII
275	11.4	15.9	13.6	17.6	6.67	11.7	3.33	149	93.6	86.6	77.3	68	XVIII
109	52.2	16.8	13.3	16.3	35	34.3	5.67	173	97.6	87.6	80.3	68.3	XIX
352	54.1	19.2	10	13.6	4.67	11.3	5.67	140	83.0	78.3	70.3	51.6	XX
98.3	28.9	22.2	11	11.5	16.6	8.3	3.33	110	74.3	67.6	60.3	56.6	XXI
779	121	16.6	13	16.7	70.3	19.7	6.67	160	97.3	88.6	79.6	70.3	XXII
178	16.7	13.9	13.3	14.1	17.3	22.6	5.67	223	104	84.6	78	71.6	XXIII
423	3.95	26.1	12.3	14.3	3.33	14.3	4.33	109	103	87.6	79	72.3	XXIV

X₁= days to 1st flowering, X₂= days to 50% flowering, X₃= days to 1st pod maturity, X₄= days to maturity, X₅= plant height (cm), X₆= number of primary branches/ plant, X₇= number of secondary branches / plant, X₈= number of pods / plant, X₉= pod size (cm), X₁₀= number of seeds / pod, X₁₁= 100 seed weight (gm), X₁₂= seed yield/ plant (gm), X₁₃= Stover yield/plant (gm).

Table 5. Contribution of different characters to divergence

Character	%Contribution to Genetic Divergence
Days to 1 st flowering	9.626
Days to 50% flowering	6.451
Days to 1 st pod maturity	6.041
Days to maturity	7.680
Plant height	8.806
No. of primary branches/ plant	7.526
No. of secondary branches/ plant	8.038
Number of pods/ plant	9.573
Pod size	8.602
Number of seeds/ pod	6.195
100 seed weight	7.680
Seed yield/ plant	6.298
Stover yield/ plant	7.475

divergence followed by days to first flowering whereas days to first pod maturity contributed minimum towards divergence.

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Characterization and Evaluation of Horsegram (*Macrotyloma uniflorum* Roxb.) Germplasm from Himachal Pradesh

RK Chahota¹, TR Sharma², KC Dhiman³ and Naval Kishore¹

¹ Department of Plant Breeding & Genetics

² Advanced Centre of Hill Bio-resources and Biotechnology

³ Seed Production Unit, CSK Himachal Pradesh Krishi Vishwavidyalaya Palampur-176 062 (Himachal Pradesh)

Sixty three landraces collected from different parts of Himachal Pradesh were evaluated in an Augmented Block Design having four checks at experimental farm of Department of Plant Breeding & Genetics, CSK HPKV, Palampur (Himachal Pradesh). The variability was assessed on the basis of 12 morpho-agronomical characters. It was observed that sufficient genetic diversity was present for days to maturity, plant height and number of pods/plant. Among the qualitative traits maximum diversity was observed for leaf colour. Disease reaction against *Colletotrichum truncatum* under field conditions revealed that most of the lines were found resistant to bean anthracnose. On the basis of evaluation data lines namely HPKC-1, HPKC-6, HPKC-7, HPKC-9, HPKM-51 and DMK-12 were found to be potential lines which can be exploited as a variety or can be used in future hybridization programme.

Key words: Horsegram, *Macrotyloma uniflorum*, Evaluation, Characterization, Germplasm

Horsegram (*Macrotyloma uniflorum* Roxb.) is an important pulse crop suitable for cultivation in many dry and marginal lands of North-western Himalayan regions comprising states of Himachal Pradesh, Jammu & Kashmir and Uttarakhand. Being a pulse crop it helps in improving the fertility status of the soil. Moreover, it can survive on drought like situations. Owing to its various medicinal uses such as horsegram lipids were shown to be protective and promote healing effects on acute gastric ulceration produced by alcohol (Jayaraj *et al.*, 2000). Besides, it is also known to dissolve and dislocate the kidney stones in human beings. Over the years, the production and area under this crop has been decreasing tremendously. One of the major reasons is the non-availability of high yielding and well-adapted genotypes, which can perform better under higher input conditions as this crop is mostly cultivated as inter crop with maize. The high yielding varieties/lines developed and grown in other parts of the country were unable to perform better when grown in Northern Hill Zones due to photo-period sensitive nature of the crop. Moreover, even within the state, the landraces being cultivated by farmers are adapted to very specific environment. Extensive screening of germplasm collected from different parts of the state is required to identify the potential lines which can either be used as improved variety or can be used in hybridization programme for introgression of desirable genes to well adapted local variety. Therefore, an attempt has been made to evaluate horsegram germplasm available in Himachal Pradesh to assess the magnitude of variability

and to identify promising accessions. The characterization of these landraces will also help the breeder to envisage an objective based breeding programme.

Materials and Methods

Sixty three lines of horsegram were collected from different parts of Himachal Pradesh ranging from 432 to 1500 m amsl (Figure 1). These lines were evaluated in augmented block design having four checks namely, HPK-4, HPKM-149, AK-21 and VLG-1 at the experimental farm of the Department of Plant Breeding & Genetics, CSK HPKV, Palampur, situated at 1290 m amsl. The experiment was conducted in *kharif*, 2003 and each entry was consisted of four rows each of 3 m length. The

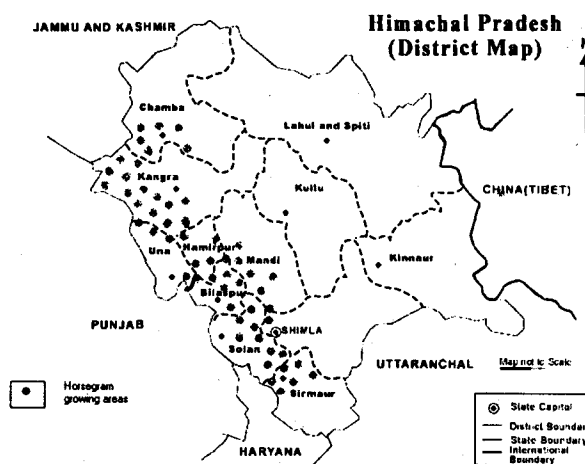


Fig. 1: Area of collection of horsegram

data were recorded on various qualitative traits namely, plant vigour, stem colour, flower colour, leaf colour, and quantitative characters such as seed yield/plant, days to maturity, days to flowering, number of pods /plant, plant height, 100-seed weight and branches/plant. Frequency distribution of various qualitative and quantitative characters was computed. Range, mean and standard deviation were calculated for quantitative characters by following standard statistical procedures.

Results and Discussion

The 63 accessions of horsegram were characterized on the basis of distinguishable phenological and agromorphological characters. Early plant vigour of most of the lines was good, while all the lines were of trailing type and were having the pubescent on leaf surface. The leaf colour of 41 lines were green 12 lines were pale green and 10 lines were dark green. Of the total lines, 35 lines had green stem and 28 lines light yellow, whereas 40 lines had pale yellow flower colour and 23 lines had yellow flower colour. The analysis of variance for quantitative traits revealed that sufficient genetic diversity was present for days to maturity, plant height and number of pods/plant (Table 1). Venkateswarlu (2000) and Tripathi (1999) have reported similar results while studying the genetic diversity in horsegram using 20 and 26 lines, respectively. The quantitative characters were

Table 1. Analysis of variance of different traits of horsegram

Source	d.f.	Mean sum of squares				
		Seed yield / plant	Days to maturity	Plant height (cm)	No. of pods/ plant	No. of branches plant
Blocks(a)	3	1.322	134.687*	680.528*	35.423*	6.890*
Blocks (b)	3	1.198	52.1667	137.035	6.251*	0.285
Entries (a)	67	1.617	70.285*	156.424	29.319*	0.744*
Entries(b)	67	1.623	73.980*	180.760*	30.626*	1.040*
Checks	3	9.961*	200.167*	126.304	30.416*	2.055*
Progenies	63	1.224	66.567*	186.201*	28.655*	0.996
Checks v/s progenies		1.692	162.4375*	1.3516	155.377*	0.800
Error	9	1.409	21.444	79.663	4.951	0.468

Table 2. Variability in quantitative characters

Quantitative trait	Range	Mean	SE of progenies in the same block	SE of progenies in the different block
Seed yield/plant	0.4-4.7	1.95	1.67	1.87
Days to maturity	92.0-120.0	117	6.55	7.32
Plant height (cm)	57.6-111.8	85.37	12.62	14.11
No. of pods/ plant	2.1-26.6	7.31	3.15	3.52
Branches/ plant	1.1-5.4	2.87	0.97	1.08

Table 3. Promising horsegram lines

Character	Line
Seed yield/plant	HPKC-6,HPKC-51, DMK-12
Days to maturity	HPKC-12, HPKM2, HPKM-16, HPKM-116
Plant height (cm)	HPKC-9, HPKC-8, HPKC-4
No. of pods/ plant	HPKC-33, HPKC-50,HPKC-17,HPKC-34, DMK-12, HPKM-51
Branches/ plant	HPKC-43

Table 4. Quantification of quantitative characters

Class	Characters				
	Seed yield/ plant (g)	Days to maturity	Plant height (cm)	No. of pods /plant	No. of branches /plant
1	0-1g	<90	>50	<5	<2
2	1-2g	91-100	50-75	5-10	2-3
3	2-3g	101-110	75-100	10-15	3-4
4	3-4g	111-120	100-125	15-20	4-5
5	>4 g	>120	>125	>20	>5

quantified into discrete classes by using different scales (Table 4). For seed yield 13 lines had the seed yield/plant less than 1g, whereas only 3 lines namely, HPKC-6, HPKM-51 and DMK-12 had seed yield/plant more than 4g. For days to maturity, it was observed that all the lines matured within 91 to 120 days and were uniformly distributed in all the three classes. Medium plant height was observed for 41 lines (65%) ranging from 75-100cm, whereas, 7 lines were having the plant height from 50-75cm. None of the lines had plant height less than 50 cm or more than 125 cm. For plant 20 and 24 lines pods per plant were between 5-10 and 10-15 respectively. Six lines namely, HPKC-33, HPKC-50, HPKC-17, HPKC-34, DMK-12 and HPKM-51 have produced more than 20 pods/plant. Thirty one lines had 2-3 branches/plant, whereas only one line, namely HPKC-43 had more than 5 branches. On the basis of evaluation of germplasm for various traits the lines namely, HPKC-1, HPKC-6, HPKC-7, HPKC-9, HPKM-51 and DMK-12 were found to be potential lines, which need to be evaluated further in multilocation trials. These lines were also evaluated for disease resistance under natural conditions by following the standard scale. Bean anthracnose (*Colletotrichum truncatum*) is an important disease appeared at early stage of growth, which causes heavy losses when appeared in epidemic (Sharma *et al.*, 1999). Data recorded for bean anthracnose with respect to disease incidence and disease severity revealed that most of the lines were moderately resistant. Whereas only three lines namely, HPKC-39, HPKC-57 and HPKC-33 were free from this disease.

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Evaluation of Some Walnut (*Juglans regia* L.) Seedling Germplasm from Himachal Pradesh

DD Sharma and JN Sharma

Dr YS Parmar University of Horticulture and Forestry, Temperate Horticultural Research Station, Kotkhai, Shimla-171 202 (Himachal Pradesh)

Kotkhai and Theog area of Shimla district was surveyed and 104 seedlings were collected. Thirty seedlings with desirable traits were selected from the total population. Maximum nut weight, nut length, suture and cheek diameter were recorded in KW 020. KW 012 recorded minimum shell thickness (1.44 mm), excellent shelling quality, light yellow kernel colour, excellent taste and highest shelling percentage (58.5%). Based on the evaluation, one seedling KW 012 was identified as the most promising selection having traits at par with international standards.

Key words: *Juglans regia*, Seedlings, Walnut, Shell, Hull

Walnut is a priced nut crop and is grown in India in North-western Himalaya at an elevation between 1200 to 2000 m above mean sea level. At present 41,840 hectare area is under walnut cultivation in India and the production is 22000 metric tonnes (FAO, 1998). Still most of the walnuts are grown as scattered seedling trees and not in well laid-out orchards. The major hurdle in the expansion of area under walnut is non-availability of vegetatively propagated plants of superior strains/cultivars. Some efforts have already been made to select superior walnut seedlings from indigenous source (Nauriyal *et al.*, 1970; Lal and Singh, 1978; Chauhan and Sharma, 1979; Sharma and Chauhan, 1980; Pandey and Sinha, 1984) as well as to introduce improved cultivars from abroad. Seedling selections/cultivars of international standard are available to a limited extent. The present study was undertaken to evaluate best seedlings available in the Kotkhai and Theog area of Shimla district of Himachal Pradesh in India and to select any seedlings which can meet all the standards needed for the export of walnuts.

Materials and Methods

A survey on walnut was conducted during 1999 in the Kotkhai and Theog area of Shimla district (altitude 1800 to 2000 m above mean sea level). 30 seedlings having desirable characters were selected out of 104 seedlings to carryout detailed studies. Data on thirty nuts selected randomly from the whole harvest of the tree after the nuts were dried to edible stage. The results were expressed on the basis of averages of triplicate sampling and analyzed statistically in a Completely Randomized Design. Nut size (represents, the nut length, suture diameter and the cheek diameter in millimeters) were measured with the help of Vernier Callipers. Weight of the in-shell nuts

was taken in grams. Kernel weight (in grams) was recorded from the same nuts used for recording the nut weight. Shelling quality and taste grades were rated on numerical scale such as 5-excellent, 4-very good, 3 good, 2-fair, 1-poor. Shelling percentage was also calculated.

Results and Discussion

The data on nut and kernel characters has been discussed in detail. However same is presented in Table 1.

Nut weight: The average nut weight varied from 9.5 g to 21.4 g. The highest nut weight was found in KW 020 followed by KW 02. The lowest nut weight was recorded in KW 05. Gouzen and Yang (1990) reported a variation in nut size in germplasm from China from 5.8 g to 27 g. For international markets an ideal nut should weigh between 12 to 18 g (McGranahan and Leslie, 1990).

Nut length: The highest nut length (47.1 mm) was recorded in KW 020 which was significantly higher than all other seedlings. The lowest nut length (29.2 mm) was recorded in KW 015.

Suture diameter: Suture diameter was found to be maximum (38.9 mm) in KW 020 which was statistically at par with KW 013. The minimum suture diameter (29.2 mm) was recorded in KW 05. For commercial grading suture diameter should not be less than 3.13 cm (Serr and Ford, 1956). A suture diameter above 3.7 cm is not considered good, as there are chances of poor filling of larger nuts.

Cheek diameter: Nuts with maximum cheek diameter (39.1 mm) were obtained from KW 020. The minimum cheek diameter (29.0 mm) was found in KW 04.

Nut shape: Three prominent shapes (conical, oblong and ovoid) were recorded in the nuts of different seedlings.

Table 1. Variation in nut characters of different walnut seedlings

Seedlings No./cultivar	Weight (g)	Length (mm)	Nut characteristics		Shape	Surface	Shell thickness (mm)	Shelling quality (grade)	Kernel characteristics		
			Suture diameter (mm)	Cheek diameter (mm)					Colour	Taste (grade)	Shelling percentage
KW01	10.7	35.2	31.4	29.2	Conical	R	2.52	3	V	2	37.5
KW02	20.2	44.1	37.2	39.7	Ovoid	R	1.91	4	V	4	42.3
KW03	14.6	38.4	33.2	31.9	Oblong	S	2.15	3	LY	5	38.3
KW04	12.9	33.2	28.4	29.0	Ovoid	S	1.97	5	Y	4	35.3
KW05	9.5	30.4	29.2	30.5	Ovoid	R	2.34	4	DY	4	39.3
KW06	15.7	40.3	32.8	34.2	Oblong	R	2.12	4	Y	3	41.8
KW07	11.5	36.5	33.4	32.2	Oblong	S	1.84	4	V	2	32.4
KW08	13.4	42.2	29.5	31.0	Conical	R	2.01	4	Y	4	46.5
KW09	14.6	39.5	34.3	31.8	Ovoid	R	2.52	3	Y	3	38.4
KW010	12.4	38.2	31.9	28.8	Conical	S	1.95	2	V	4	35.2
KW011	10.8	35.1	32.6	33.4	Oblong	R	2.46	3	DY	3	32.4
KW012	15.4	35.2	36.3	38.4	Ovoid	S	1.44	5	LY	5	58.5
KW013	19.4	42.5	38.8	38.7	Ovoid	R	2.31	3	LY	5	34.5
KW014	12.2	38.2	30.4	31.2	Oblong	R	2.18	4	Y	4	37.3
KW015	9.80	29.2	31.2	30.4	Conical	R	1.91	3	Y	4	33.4
KW016	14.3	35.0	36.4	32.2	Ovoid	R	2.13	4	LY	5	42.2
KW017	19.2	41.4	38.4	33.4	Oblong	S	1.88	5	V	3	48.4
KW018	11.3	33.4	32.2	30.7	Ovoid	S	2.08	5	Y	2	40.4
KW019	10.2	38.2	32.4	31.4	Oblong	R	1.95	4	Y	4	35.2
KW020	21.4	47.1	38.9	39.1	Oblong	R	2.28	4	V	3	47.3
KW020	21.4	47.1	38.9	39.1	Oblong	R	2.28	4	V	3	47.3
KW021	15.7	39.2	30.2	31.4	Conical	S	2.02	5	Y	4	43.7
KW022	14.8	37.2	34.4	33.2	Oblong	S	2.62	2	LY	5	28.3
KW023	13.3	36.5	33.0	32.1	Oblong	R	2.55	3	DY	3	29.4
KW024	11.7	38.2	30.2	29.4	Conical	R	1.83	4	Y	4	43.7
KW025	15.3	35.4	33.8	34.2	Ovoid	R	2.57	3	V	2	33.4
KW026	12.8	37.4	30.2	28.7	Conical	S	1.62	5	DY	3	44.2
KW027	13.7	35.0	33.2	32.4	Ovoid	R	2.44	4	LY	5	35.2
KW028	18.4	40.4	35.3	34.7	Oblong	S	2.36	4	DY	4	39.4
KW029	12.1	37.2	30.4	29.2	Conical	R	2.25	4	Y	3	41.4
KW030	11.2	33.4	32.2	31.4	Ovoid	S	1.81	4	LY	5	42.3
CD00:5	3.62	2.46	3.84	4.27	—	—	0.33	—	—	—	7.84

Nut surface: R-rough; S-smooth

Kernel colour: V-violaceous; DY-dark yellow; Y-yellow; LY-light yellow

Shelling quality: 5-excellent; 4-very good; 3-good; 2-fair; 1-poor

Sharma and Sharma (1998) also found wide variation in 125 seedling germplasm.

Nut surface: Out of 30 seedlings, the nut surface of 18 seedlings was rough and 12 was smooth. Shell surface varied from slightly grooved to deeply grooved. Nuts having minimum grooved surface were more desirable. Sharma and Sharma (1998) reported variation in shell surface as slightly grooved (72 trees), moderately grooved (46 trees) and deeply grooved (7 trees).

Shell thickness. Highest shell thickness (2.62 mm) was recorded in KW 022 whereas it was lowest (1.44 mm) in KW 012. Medium shell nuts can be marketed as in-shell and thin shelled nuts as kernels. Bhat *et al.* (1992) found that out of 20 seedlings, 4 were hard shelled, 14 were medium shelled and 2 were thin shelled.

Shelling quality: Shelling quality is a very important parameter as it determines whether the whole kernel

is removed neatly or as broken pieces. Excellent shelling quality was observed in KW 04, KW 012, KW 017, KW 018 and KW 026. Poor shelling quality was found in KW 010 and KW 022.

Kernel colour: For good quality walnuts, light yellow kernel is a desirable character. KW 03, KW 012, KW 013, KW 016, KW 022, KW 027 and KW 030 were accessions having light coloured kernels. Bhat *et al.* (1992) recommended light amber coloured kernel.

Kernel taste: Five local seedlings KW 03, KW 012, KW 013, KW 022 and KW 027 were found to have an excellent taste with numerical value of 5. Taste of KW 01, KW 07, KW 018 and KW 025 was observed to be the poor quality.

Shelling percentage: Highest shelling percentage (58 %) was recorded in KW 012 which was significantly higher than other seedlings. The lowest percentage (29.4%) was,

however recorded in KW 023. According to Serr and Ford (1956) an ideal nut should have above 50 per cent kernel percentage. However, 50 to 60 per cent is desirable. Bhat *et al.* (1992) reported three seedlings namely Wossan-4, P-I and V-I having a shelling percentage of 63.60, 63.0 and 62.0 per cent, respectively.

The variability in all the characters is mainly due to the heterozygous nature of plants obtained from seed. Hansche *et al.* (1972) have reported that shell thickness, nut weight and kernel weight have high heritability characters. Therefore, these traits should be considered for seedlings selection programme. For international market an ideal nut should weigh between 12-18 g with a clean strong and thin shell with tight seal and easily removable light clear and plump kernel weighing at least 50 per cent of the in-shell nut (Mc Granahan and Leslie, 1990). In the present study the nut size of KW 012 was found to be medium (15.4 g) with the highest shelling percentage (58.5%). It is thin shelled (1.44 mm) and also possesses excellent shelling quality and taste. Its hull splits without leaving stain on the nut. Therefore, KW 012 was found to be the most promising selection going at par with international standard.

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Screening of *Dioscorea* Species for Diosgenin from Southern Western Ghats of India

KI Asha¹ and GM Nair²

¹National Bureau of Plant Genetic Resources Regional Station, Vellanikkara, Thrissur-680 656 (Kerala)

²Tropical Botanical Garden and Research Institute, Palode, Thiruvananthapuram (Kerala)

Dioscorea deltoidea Wall. is the major species exploited in India for diosgenin obtained from rhizomes. The natural stock of *D. deltoidea* being exhausted due to large-scale collection from forest areas and very poor rate of regeneration, leads to apprehensions that this important raw material may completely be lost to the industry if steps to conserve the stocks are not taken up immediately. Preliminary screening of different species locally available to identify new sources of diosgenin identified leaf samples to show presence of diosgenin in all the twelve species while tuber samples of only 4 species viz., *Dioscorea hispida*, *D. hamiltonii*, *D. spicata* and *D. pubera* revealed its presence. Of these, the maximum diosgenin yield was recorded in *D. pubera* (1220 µg/g d. wt.) followed by *D. spicata* (305 µg/g d. wt.), *D. hispida* (57 µg/g d. wt) and *D. hamiltonii* (3 µg/g d. wt.).

Key words: *Dioscorea*, Diosgenin, Yams

Diosgenin is the most important and versatile precursor of steroidal drugs obtained from rhizomes of various species of *Dioscorea*, which account for about 50% of the total steroidal drug output in the world. Diosgenin occurs naturally in a number of plant genera such as *Dioscorea* (Dioscoreaceae), *Costus* (Zingiberaceae), *Trillium*, *Paris* (Liliaceae), *Balanites* (Simarubiaceae) and *Trigonella* (Leguminosae). Correll *et al.* (1955) reported that species of *Dioscorea* were the ideal source of diosgenin.

Dioscorea deltoidea Wall. is the major species exploited for diosgenin in India. The raw material comes exclusively from forest areas as the plant has shown discouraging performance under domestication. The natural stock of *D. deltoidea* is gradually being exhausted due to large-scale collections from these forest areas accompanied with a very poor rate of regeneration which leads to apprehensions that this important raw material may be completely lost if steps to conserve the species are not taken up immediately.

Under the above circumstances, a preliminary screening of the different species locally available becomes necessary, to identify new sources of diosgenin for commercial use. In the present study, the leaf and tuber samples of field grown plants of 12 wild species, originally collected from the Southern Western Ghats, grown under uniform conditions were screened for diosgenin, adopting the standard methodology.

Materials and Methods

Materials selected for the study includes one accession each from 12 species of *Dioscorea* procured from NBPGR Regional Station, Thrissur and grown in the greenhouse

of Department of Botany, University of Kerala, Thiruvananthapuram, Kerala (Table 1). The extraction and analysis of diosgenin in the different *Dioscorea* species was based on the procedures adopted by Li *et al.* (2002) in *Dioscorea zingiberensis*. Preliminary screening for the presence of diosgenin was carried out using leaf samples taken during the intensive vegetative growth period. Further, tuber samples of these species, grown *in vivo*, harvested in January having uniform stages of growth were also subjected to screening and quantification for diosgenin. Leaf samples were air dried and powdered. The tuber samples after through washing and blotting were sliced and oven dried at 60°C for 48 hours and then powdered. 1g each of the powdered leaf / tuber sample was extracted with 20 ml 2N HCl for 3½ hours by periodical stirring and cooled to room temperature and filtered. The filtrate thus obtained was neutralized with 2N NaOH and allowed to dry by evaporation. The pelleted out filtrate was extracted with 5 ml chloroform and stored. The residue thus obtained was washed thoroughly in water to remove the acid content completely and dried at 78°C for 4 hours in an oven and was extracted with petroleum ether (40-60°C bp) at room temperature and filtered. The filtrate was evaporated and pelleted out. The pellet thus obtained was extracted with 5ml chloroform and the two chloroform extracts were mixed thoroughly and analyzed by TLC and HPLC using the reference sample of diosgenin from Sigma Aldrich, USA.

Thin Layer Chromatography (TLC) (Li *et al.*, 2002)

TLC plates were prepared using silica gel (G-60 Merck) as the absorbent. Slurry of silica gel with distilled water, 1:2 (w/v) ratio, was spread on 5 mm thick glass plate

*Author for correspondence, e-mail: ashakarthy@rediffmail.com

Table 1. Materials analyzed

Species	IC Number	Locality of collection
<i>Dioscorea bulbifera</i> L.	202349	Peechi, Thrissur, Kerala
<i>Dioscorea pentaphylla</i> L.	202367	Peechi, Thrissur, Kerala
<i>Dioscorea hispida</i> Dennst	202370	Nilambur, Malappuram, Kerala
<i>Dioscorea tomentosa</i> Heyne	202379	South Canara, Karnataka
<i>Dioscorea pubera</i> Bl.	202382	Begur, Wynad, Kerala
<i>Dioscorea intermedia</i> Thw.	202384	Santhanpara, Idukki, Kerala
<i>Dioscorea spicata</i> Roth.	202383	Thirthahally, Coorg, Karnataka
<i>Dioscorea oppositifolia</i> L.	202386	Valpara, Palghat, Kerala
<i>Dioscorea wightii</i> Hook. f.	214855	Mundanthurai, Tamil Nadu
<i>Dioscorea belophylla</i> Voight	248181	Devakolly, Coorg, Karnataka
<i>Dioscorea wallichii</i> Hk. f.	202312	Courtallum, Tirunelveli, Tamil Nadu
<i>Dioscorea hamiltonii</i> Hk.	202328	Vadakkancherry, Thrissur, Kerala

(20 x 20 cm) with the help of a TLC applicator, which was adjusted to a thickness of 0.5 mm. The plates were dried at room temperature and activated at 100°C for 30 minutes in a thermo regulated hot-air oven.

100 µl each of the different samples (leaf and tuber) were spotted on to the activated silica gel TLC plates along with authentic reference sample of diosgenin at 2 cm from the bottom, using calibrated micro syringes and the spots were allowed to dry. Meanwhile, the required quantity of solvent system *i.e.* Chloroform:Petroleum ether (40-60°C bp) 4:1 (v/v) was taken in the chromatographic chamber, closed tightly and kept for half an hour in order to create a saturated condition inside the chamber. The plates with the sample spots, after drying, were kept in a slanting position inside the chromatographic chamber and sealed tightly. After sufficient solvent percolation and when the solvent front reached three fourth of the total length of the glass plate, the chromatograms were taken out, solvent front was marked and allowed to dry. The air-dried plates after sufficient solvent percolation were sprayed with 20% sulphuric acid (v/v) and heated at 100°C for 25 min. resolved purple coloured spots, which corresponds to diosgenin. Presence of diosgenin in the samples was identified as pink spots corresponding to the *R_f* value of the standard diosgenin.

The retention factor was calculated as:

$$R_f = \frac{\text{Distance travelled by the spot}}{\text{Distance travelled by the solvent system}}$$

High Performance Liquid Chromatography (HPLC)

HPLC analysis of the tuber samples was carried out in a Shimadzu LC-10AS liquid chromatography system equipped with UV detector and a Shimpac C-18 column (Shimadzu, Japan). The mobile phase used was methanol:water (95:5) with a flow rate of 1 ml / min. The samples were filtered through a nitrocellulose filter (20 micron). 20 µl each of the filtered samples were injected one at a time into the machine using a micro injector. The absorbance of diosgenin was detected at 210 nm using the UV-visible detector (Shimadzu SPD-IDA, Japan). The chromatogram was analysed using e-R7Ae Plus (Shimadzu, Japan) Chromatopac System. The quantity of diosgenin in each sample was calculated and compared with the authentic sample of diosgenin.

Identification and Quantification of Diosgenin

Diosgenin content in the crude extracts of leaf and tuber samples of different species grown in the field under identical conditions was subjected to TLC and HPLC. After preliminary screening of the leaves by TLC, the tuber samples were subjected to TLC and then HPLC for quantification.

Results and Discussion

Detection of diosgenin in the samples by TLC

Preliminary screening of leaf samples showed diosgenin in all the twelve species under investigation. Amongst these, the presence of diosgenin in tubers was revealed only by 4 species namely *D. pubera*, *D. spicata*, *D. hispida* and *D. hamiltonii* as purple coloured spots at an *R_f* value of 0.37.

Quantification of diosgenin in samples by HPLC

The quantification of diosgenin in the tuber samples of the 12 species of *Dioscorea* revealed the presence in only 4 species *viz.* *D. hispida*, *D. hamiltonii*, *D. spicata* and *D. pubera*. The retention times (RT) of the different species that contain diosgenin namely *D. pubera*, *D. spicata*, *D. hispida* and *D. hamiltonii* were 8.089, 8.12, 8.146 and 8.126 minutes, respectively (Table 2), which corresponded with the RT of diosgenin standard 8.094 minutes (Table 2). Of these, the maximum diosgenin yield was recorded in *D. pubera* (1220 µg/g d. wt.) followed by *D. spicata* (305 µg/g d. wt.), *D. hispida* (57 µg/g d. wt.) and *D. hamiltonii* (3 µg/g d. wt.). The other 8 species lack diosgenin in tubers as revealed by both TLC and HPLC. These species contained a number of unidentified compounds, as revealed in the HPLC profile (Table 2).

Earlier studies on the growth of tubers and diosgenin content in *Dioscorea deltoidea* (Shah *et al.*, 1998; Chauhan, 1999), *D. zingiberensis* (Li *et al.*, 2002) and *D. composita* (Zullo *et al.*, 1987) revealed contents to be directly proportional to age.

An interesting correlation between morphological characters and diosgenin content has been elucidated based on the studies of the Japanese *Dioscorea* species (Akahori, 1965). In this, analysis of 3 of the Japanese species of *Dioscorea*, which did not contain sapogenin revealed that species with alternate leaves, stems twining to the left and no bulbils contained diosgenin, whereas, the species with opposite leaves and stems twining to the right with edible roots lacks diosgenin. Contrary to these result, *D. bulbifera*, which though has stems twining to the left and globose tuber and forms bulbils, was not containing diosgenin (Hegnauer, 1963; Kaul and Staba, 1968 and Quigley, 1978).

Correlation studies on diosgenin content with flesh colour revealed lower contents for white flesh tubers in *D. floribunda* and *D. deltoidea* (Singh *et al.*, 1999) while the later for *D. deltoidea* showed higher concentrations for white flesh of tubers (Bindroo, 1988; Kant *et al.*, 1998). The present analysis involving the different species of *Dioscorea* showed higher diosgenin content for coloured fleshed tubers (*D. pubera*, orange yellow tuber) than the white ones. Hence, utilization of tuber flesh colour as an indicator for higher diosgenin content as suggested by Kant *et al.* (1998) may not be dependable in visual screening of different *Dioscorea* species.

From the present investigation it can be established that the South Indian species of *Dioscorea* contain diosgenin. The lower diosgenin content presently detected in the species may be due to the interaction of environmental factors or may be due to genetic make up of the parent clones.

Out of the 12 species studied, only 4 showed the presence of diosgenin in their tubers. In *Dioscorea* species, site of synthesis is reported to be the leaves and the metabolites are then translocated by the stem to the tubers for long-term storage. Bennett *et al.* (1963) suggested that diosgenin is biosynthesized principally in the aerial parts of *D. spiculiflora* and is then rapidly translocated to the tubers. Blunden *et al.* (1968) found that the total sapogenin yield was 6-40 times greater in leaves than the stems in *D. sylvatica*, *D. prazeri*, *D. floribunda*, *D. composita* and *D. deltoidea*. Contradictory to this, Kant *et al.* (1998) found that no diosgenin occurs either in

Table 2. HPLC profile of various compounds present in different species of *Dioscorea*

Diosgenin/Plant species	Retention time	Concentration
Diosgenin (standard)	8.09	8.466
<i>Dioscorea bulbifera</i>	1.37	12.014
	2.29	2.232
	3.06	7.129
	3.35	72.614
	4.41	1.833
	6.57	2.677
<i>Dioscorea pentaphylla</i>	1.41	13.129
	3.41	70.798
	4.48	6.116
	5.58	2.531
	6.01	1.612
	6.63	4.047
<i>Dioscorea hispida</i>	2.1	13.096
	3.35	65.270
	4.20	2.920
	4.40	7.138
	5.32	1.282
	5.49	1.036
	5.93	4.402
	6.58	4.703
	8.146	0.0397
<i>Dioscorea tomentosa</i>	2.22	14.722
	3.36	61.128
	4.42	16.612
	5.94	2.323
	6.57	4.373
<i>Dioscorea pubera</i>	3.43	80.822
	4.49	7.870
	6.71	5.542
	8.09	1.189
<i>Dioscorea intermedia</i>	0.90	15.859
	3.43	77.226
<i>Dioscorea spicata</i>	2.52	14.255
	3.24	6.205
	3.45	47.779
	3.83	7.379
	5.35	8.028
	8.12	0.208
<i>Dioscorea oppositifolia</i>	1.95	15.135
	3.39	65.115
	4.45	5.904
	4.62	9.642
<i>Dioscorea wightii</i>	2.48	12.298
	3.27	5.709
	3.47	58.564
	4.58	6.216
	4.72	12.584
<i>Dioscorea belophylla</i>	1.43	14.463
	3.44	53.634
	3.83	9.506
	4.50	9.669
<i>Dioscorea wallichii</i>	2.58	16.423
	3.35	69.657
	4.39	7.089
<i>Dioscorea hamiltonii</i>	2.35	12.585
	3.35	67.656
	5.31	14.286
	8.13	0.022

the leaves or stems of *D. deltoidea*, though yamogenin in traces has been found in the stem and leaves of the species *D. deltoidea*. But the presence of diosgenin in leaf samples of all the 12 species and its absence in the tubers of 8 species indicated that the genus *Dioscorea* is characterized by the presence of the secondary metabolite diosgenin, but the species show distinct variation in translocation of the molecules from the site of synthesis to the site of accumulation.

In short, the present investigation reveals the presence of diosgenin in the species from Southern Western Ghats, which in future can be exploited by the pharmaceutical industry to meet the ever-increasing demand of diosgenin.

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Classification and Selection of Representative Varieties of *Eruca sativa* Mill. (Taramira)

AP Mishra*, AK Singh, Arvind Kumar and Sanjay Kumar

National Research Centre on Rapeseed-Mustard, Bharatpur-321 303 (Rajasthan)

A total of 235 accessions of *Eruca sativa* Mill. (Taramira), including two checks were grown in augmented design for evaluation. Observations on 11 characters namely plant height; primary branches per plant, secondary branches per plant; main shoot length, number of siliqua on main shoot, siliqua length, number of seeds per siliqua, yield per plant, 1000-seed weight, oil content and protein content were recorded. Oil content and protein content together were also calculated for this study. Using principal component analysis, all the 235 accessions, were classified into nine clusters. Subjective classification of different characters between the clusters based on coefficient of variance was also done. It revealed that there are significant differences in the pattern of subjective classification of different characters between the clusters.

Key words: Taramira, *Eruca sativa* Mill., Cluster analysis, Principal component analysis, Subjective classification

Eruca sativa Mill. (taramira), a rapeseed and close relative of mustard is believed to be a native of southern Europe and North Africa. It is grown in the drier part of North-west India comprising the states of Punjab, Haryana, Uttar Pradesh and Rajasthan. Maintenance of a huge germplasm of rapeseed at the National Research Centre on Rapeseed-Mustard (NRCRM), Bharatpur, Rajasthan is not only a cumbersome task but also quite difficult for the breeders, to select the varieties for breeding programme. Hence, this study was carried out to classify huge taramira germplasm into different groups based on principal component analysis (Jaiswal and Sangwan, 1998). The representative varieties of different groups are also selected to make ease of the breeder to maintain and select the varieties for breeding purposes (Mishra *et al.*, 1991).

Materials and Methods

Two hundred and thirty five accessions including checks of *Eruca sativa* (taramira) were grown in augmented design for germplasm evaluation during *rabi* 1999-2000-01 at the National Research Centre on Rapeseed-Mustard, Bharatpur (Rajasthan). Two check varieties (RTM-314 and T-27) were grown repeatedly after each ten accession to evaluate the new one. Each accession was sown on two rows of four-meter at 45 cm distance and plant-to-plant spacing of 15 cm was maintained by thinning. Recommended doses of fertilizer (N: P: K@ 40:20:0 kg/ha) were applied. Suitable agronomic practices and plant protection measures were adopted.

Observations were recorded on five randomly selected plants. The traits studied were plant height (cm); primary

branches per plant (nos.); secondary branches per plant (nos.); main shoot length (cm); siliqua on main shoot (nos.); siliqua length (cm); seed per siliqua (nos); yield per plant (gm); 1000-seed weight (gm); oil content (%) and protein content (%). Oil content plus protein content together were also considered for the classification.

Results and Discussion

A total of 235 accessions of taramira comprising BPTM 1 to 233 and two check varieties RTM-314 and T-27 have been classified in to 9 clusters (Mishra *et al.*, 1991 and 1998). Cluster, numbers of accession (N), within mean sum of square and cluster members were presented (Table 1). Considering within mean sum of square it revealed that most diverse cluster was cluster number 2 (10.18), followed by cluster number 5 (7.53), cluster number 7 (7.42), cluster number 4 (7.16), cluster number 1 (6.71), cluster number 6 (6.20), cluster number 8 (6.18), cluster number 3 (5.90) and cluster number 9 (4.32) (Table 1).

The mean, coefficient of variance (CV) and percentage contribution to divergence of different characters under study are presented (Table 2). The most divergent character was secondary branches per plant (CV = 32.42) followed by yield per plant (CV = 31.73); primary branches per plant (CV = 21.61); main shoot length (CV = 14.4); siliquae on main shoot (CV = 12.78); plant height (CV = 10.79) etc. (Table 2). If percentage contribution towards divergence for the individual characters kept in descending order like 1000-seed weight (10.60%); seed per siliqua (10.24%); main shoot length (9.34%); yield per plant (9.14%); plant height (8.55%); siliqua length (8.34%);

*Author for correspondence

Table 1. Classification of 235 *Eruca sativa* Mill. accessions into 9 clusters

Cluster (BPTM)	Accession Number in Cluster	Within MSS	Cluster members
1	30	6.71	104; 71; 27; 24; 77; 128; 10; 130; 56; 118; 115; 109; 107; 78; 26; 129; 131; 122; 125; 25; 121; 28; 113; 127; 116; 123; 167; 126; 124; 132
2	14	10.18	117; 74; 165; 135; 76; 136; 143; 204; 139; 140; 142; 144; 137; 141
3	37	5.90	194; 3; 227; 229; 186; RTM-314; 1; 228; 181; T-27; 119; 231; 225; 199; 99; 179; 213; 134; 138; 156; 201; 191; 189; 173; 112; 180; 200; 205; 114; 215; 206; 230; 198; 190; 188; 208; 32
4	15	7.16	57; 192; 233; 174; 232; 153; 154; 21; 8; 193; 168; 146; 160; 145; 159;
5	30	7.53	59; 106; 61; 23; 7; 4; 14; 67; 212; 12; 20; 11; 65; 19; 13; 5; 152; 16; 30; 66; 158; 68; 149; 18; 148; 17; 147; 150; 161; 151
6	21	6.20	98; 92; 84; 89; 81; 87; 80; 79; 95; 91; 90; 86; 94; 82; 111; 85; 83; 93; 100; 110; 162
7	35	7.42	203; 226; 101; 172; 202; 97; 184; 219; 170; 178; 196; 169; 103; 222; 2; 88; 163; 105; 120; 183; 166; 108; 64; 157; 171; 182; 164; 175; 102; 197; 177; 176; 195; 185; 223
8	18	6.18	155; 44; 210; 214; 39; 216; 211; 36; 224; 209; 35; 49; 220; 217; 221; 218; 207; 33
9	35	4.32	52; 62; 75; 53; 72; 63; 60; 38; 55; 70; 69; 54; 50; 42; 41; 15; 187; 9; 22; 48; 37; 58; 46; 133; 51; 40; 47; 45; 6; 73; 43; 29; 31; 34; 96

Table 2. Mean, CV and percentage contribution to divergence of different characters under study

Character	Mean	CV	Percentage contribution to divergence
Plant height (PH)	84.55	10.79	8.55
Primary branches (PB)	7.45	21.61	8.33
Secondary branches (SB)	14.96	32.42	7.85
Main shoot length (MSL)	38.48	14.40	9.34
Siliquae on main shoot (SMS)	17.06	12.78	7.59
Silique length (SL)	1.92	8.85	8.34
Seeds per silique (SS)	19.3	9.17	10.24
Yield per plant (YPP)	9.77	31.73	9.14
1000 seed weight (1000 SW)	4.11	6.81	10.60
Oil content (OC)%	35.12	1.74	8.33
Protein content (PC)%	22.51	2.22	6.86
OC and PC	57.63	1.35	4.42

primary branches (8.33%) and oil content (8.33%), these eight characters explained 72.87% variation (Table 2), whereas, the principal component analysis revealed that only five principal component explained 73.72% and eight principal component explained 93.20% towards genetic divergence (Hepziba *et al.*, 1995). Therefore, use of principal component is more appropriate than the use of individual character's contribution towards the study of genetic divergence.

Seed is usually marketed for both oil and protein content but oil content is negatively correlated to protein content in taramira (Table 3). In the evaluated accessions of taramira, oil content, protein content and oil plus protein content were not observed to be important characters for the study of the genetic divergence (CV's are 1.74; 22.2 and 1.35 % respectively) (Table 2) (Aluko and McIntosh, 2001). After comparing the Table 2 and 3

simultaneously, highly correlated variable oil content with oil plus protein content ($r^2 = 0.726$) and PC with OC plus PC ($r^2=0.533$) could be ignored but important variables for breeding purposes such as SB, PB ($r^2 = 0.689$); SMS, MSL ($r^2 = 0.564$); SS, SL ($r^2 = 0.538$); MSL, PB ($r^2 = 0.486$); YPP, SB ($r^2 = 0.459$) and 1000-SW, YPP ($r^2 = 0.375$) could be selected.

Characteristics of classified clusters

All the 235 accession of taramira were classified into nine distinct clusters. The feature of the distinct cluster is explained as cluster number 3 had 37 accessions including two check varieties (RTM-314 & T-27). It revealed that accessions of cluster number 3 had the characteristics of two check varieties and the most variable characters in cluster number 3 is YPP followed by SB, PB and SMS (Table 4). Cluster number 9 had unique feature in CV not more than 2.846 in any character under

Table 3. Correlation coefficient of different characters

Character	Correlation matrix											
	PH	PB	SB	MSL	SMS	SL	SS	YPP	1000-SW	OC	PC	OC&PC
PH		0.106	0.302	0.203	0.294	0.026	-0.033	0.362	0.282	-0.304	-0.027	-0.281
PB			0.689	0.486	0.204	0.004	-0.089	0.172	0.041	0.054	-0.141	-0.053
SB				0.308	0.232	-0.034	-0.059	0.459	0.099	-0.004	-0.181	-0.129
MSL					0.564	0.169	0.021	-0.059	0.096	-0.006	-0.106	-0.079
SMS						0.038	0.003	0.177	0.103	-0.059	-0.161	-0.164
SL							0.538	0.035	0.097	-0.084	0.124	0.015
SS								0.147	-0.147	-0.028	0.001	-0.024
YPP									0.375	-0.190	-0.119	-0.248
1000-SW										-0.105	-0.020	-0.105
OC											-0.195	0.726
PC												0.533
OC&PC												

Table 4. Coefficient of variance of individual characters along with over all CV in different clusters

Character	Cluster (CV)									Overall CV
	1	2	3	4	5	6	7	8	9	
PH	9.508	7.443	9.891	12.906	11.686	9.083	8.915	10.881	2.846	10.79
PB	22.431	20.759	13.970	22.062	18.426	17.528	11.779	24.436	0.372	21.61
SB	29.458	35.233	35.694	34.071	17.034	17.512	19.534	66.640	0.864	32.42
MSL	14.911	11.959	9.681	9.497	12.685	10.391	10.271	16.269	1.006	14.4
SMS	13.596	17.685	10.926	11.545	10.204	16.182	13.594	11.941	0.617	12.78
SL	7.112	12.077	8.062	12.348	8.898	9.176	9.936	7.059	0.051	8.85
SS	10.188	6.685	9.025	8.524	7.458	6.473	8.848	10.724	0.550	9.17
YPP	33.171	37.542	40.853	22.860	40.093	37.405	29.249	41.803	1.390	31.73
1000-SW	12.905	8.041	10.013	11.398	12.434	9.807	10.173	12.762	0.158	6.81
OC	1.804	2.259	3.154	1.513	2.331	2.230	1.871	1.726	0.202	1.74
PC	2.545	5.926	3.735	1.844	2.446	2.360	2.839	2.717	0.143	2.22
OC & PC	1.448	2.411	2.936	0.644	1.456	1.292	1.496	1.419	0.204	1.35

study (Table 4). Cluster number 1 had the most variable characters YPP followed by SB, PB and MSL. The most variable characters in cluster number 2 was also YPP followed SB, PB and SMS. Cluster number 4 and number 8 had most variable characters SB followed by YPP and PB but separated by the forth-variable character i.e. PH in cluster number 4 but MSL in cluster number 8 (Mishra *et al.*, 1998).

Similarly, cluster number 5 and number 6 had most variable characters YPP followed by PB and SB but it can be distinguished with the forth-variable character MSL in cluster number 5 and SMS in cluster number 6. Cluster number 7 can identify with the characteristics of most variable character YPP followed by SB, SMS and PB. Presence of some peculiar characteristics in every cluster may help the breeders to select the clusters having characters of their choice for their breeding programme.

Ignoring the three characters namely oil content, protein content and oil plus protein content because of their low CV's (< 6%), the subjective classification of

rest characters in the different clusters was made based on their CV's (Table 5). Chi-square test was applied to the subjective classification. The calculated, chi-square value at 3 d.f. was significant at 1 % level of significance (Calculated value = 14.28; tabulated value = 11.34). It can therefore, be concluded that there are significant differences in the pattern of presented subjective classification of different agro-morphological characters between the clusters and classification of all the accessions into nine clusters.

The study was also an attempt to select the few representative varieties from the different classified clusters to make ease for the scientists to maintain the germplasm. For this purpose individual recorded observation of different characters in different clusters and over all mean of the all the characters of 235 accessions was taken into account.

The observed record of characters in different clusters that were more than over all mean were selected and taken into consideration to select the representative

Table 5. Subjective classification of different characters between the clusters based on CV

Characters	1	2	3	4	5	6	7	8	9
PH	L	L	M	H	H	L	L	M	VL
PB	H	H	L	H	M	M	L	H	VL
SB	M	H	H	H	L	L	L	H	VL
MSL	H	H	L	L	H	M	M	H	VL
SMS	H	H	M	H	M	H	H	H	VL
SL	L	H	L	H	L	L	L	L	VL
SS	M	L	L	L	L	L	L	M	VL
YPP	M	H	H	L	H	H	L	H	VL
1000-SW	H	L	M	H	H	L	M	H	VL

VL = Very less ; L = Less ; M = Medium ; H = High

varieties of the individual cluster. Individual variety of different clusters was selected as representative varieties, which ranked first more times in respect to individual character of that particular variety (Mishra *et al.*, 1998). All the selected 59 representative varieties of different clusters were presented in Table 6. By this, we can suggest to maintain only 59 accessions (25%) in place of 235 accessions and taken into account for breeding programme, selecting the varieties from the individual cluster with specific character which suits the breeder for their breeding programme.

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Table 6. Representative varieties of different clusters

Cluster/Total Number of Varieties	Representative varieties (BPTM)
1(8)	10; 118; 115; 131; 122; 125; 167; 132
2(5)	117; 165; 135; 139; 144;
3(9)	194; 3; 1; 119; 179; 134; 112; 188; 32
4(5)	232; 193; 146; 145; 159
5(9)	59; 61; 4; 212; 12; 68; 18; 150; 151
6(6)	98; 84; 111; 83; 100; 110
7(9)	226; 219; 196; 222; 2; 183; 182; 175; 223
8(4)	155; 216; 221; 207
9(4)	60; 42; 22; 58

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Evaluation of Forage Sorghum Germplasm

R Yadav, SK Pahuja and RPS Grewal

Forage Section, Department of Plant Breeding, CCS Haryana Agricultural University, Hisar-125 004 (Haryana)

The germplasm lines generated at Hisar and collected from different sources were evaluated for forage traits like multicut traits, leaf characteristics, height, fodder yield and biotic stresses for over three to five years. Wide range of variability was observed for all the characters studied. Maximum variability was observed for days to 50% flowering followed by leaf area index, leaf length, number of leaves per plant, plant height, regeneration potential, TSS, green fodder yield and dry fodder yield per plant. To exploit the fodder yielding potential and for improvement in other traits of forage sorghums, taking into account different aspects of the current and future emphatic areas these germplasm resources can be utilized.

Key words: Forage sorghum, Evaluation, Germplasm, Growth rate, Regeneration

Presence of remarkable range of adaptability of sorghum in varying altitude, temperature, moisture, fertility, disease and pest regimes makes it a favourable choice to bridge the gap between demand and supply of fodders. Developing superior varieties/hybrids offers solution to the problem of sustained and increased fodder supply per unit area and per unit time. The greater utilization of the genetic diversity in developing sustainable solutions to basic crop constraints or enhancing the productivity is desirable. Germplasm forms the base material for any crop improvement programme and the importance of broad genetic base in evolving new cultivars and for incorporating new genes in the existing ones is well recognized. However, only a small fraction of total available collection could be fully utilized at a time due to certain limitations. For its efficient utilization, it must be properly evaluated, characterized and documented. Therefore, careful characterization and evaluation of sorghum germplasm for morpho-physiological characters and resistance to insect-pests and diseases is required.

Materials and Methods

The changing biotic and abiotic environments over years allow differential expression of entries. Therefore, about 200 to 250 germplasm lines were evaluated over three to five years during 1996 to 2002 for different traits at Forage Research Area, CCS HAU, Hisar (Haryana). An important aspect often ignored and underestimated is the tremendous knowledge about sorghums available with local farmers. Considering this aspect, 56 lines collected from fields of farmers of Western Uttar Pradesh and Uttaranchal, the major forage sorghum growing areas, were also incorporated in this study.

Most of the material (having G and S numbers) was generated at CCS HAU, Hisar and the lines with

IS numbers were obtained from ICRISAT, others which are denoted by names of the places were collected from different places in Western Uttar Pradesh and Uttaranchal. These lines were grown along with two checks (HC 308 and SSG 59-3) in augmented design. Each block consisted of ten germplasm lines and two checks. Number of blocks varied from 20 to 25 every year depending on the number of lines evaluated. Each entry was grown in two rows of 4 m length for 3 or more years. All the package of practices to raise a good crop were followed. The observations were recorded on five randomly selected plants for important forage traits viz., early vigour (score), days to 50% flowering, plant height (cm), leaf length (cm), leaf breadth (cm), leaves per plant, stem girth (cm), tillers per plant, leaf stem ratio, leaf area index (cm²), nodes per plant, regeneration potential (%), growth rates (0-30, 30-45 and 45-60 DAS), TSS (Brix %), grey leaf spot (score), zonate leaf spot (score), sooty stripe (score), stem borer (score) and green and dry fodder yield per plant (g). For obtaining regeneration potential of a genotype, tillers per plot before taking cut and after taking cut (regenerated crop) were counted and their per cent increase or decrease was taken as regeneration potential. For growth rates, plant height was recorded in centimeters at 30, 45 and 60 days after sowing (DAS). Growth rate per day was calculated by dividing the height gained by number of days of that particular growth period. Analysis was carried out on the basis of averages calculated over the years.

Observations were recorded at 35 and 55 days after sowing for three foliar diseases viz., grey leaf spot (*Cercospora sorghi*), zonate leaf spot (*Gloeocercospora sorghi*) and sooty stripe (*Ramulispora sorghi*). Scoring was done using visual standards employing the 1-5 scale,

Table 1. Range and top ranking genotypes for various characters in forage sorghum

S.No.	Character	No. of Genotypes	Range (all genotypes tested)	Criteria for best genotypes	Names of top ranking genotypes
1	Early Vigour (score)	312	1-4	=4	IS 3234-1, IS 3375-2-1, IS 4478, IS 4526, IS 4636, IS 4735-1, IS 4736, IS 4782, IS 23324, IS 23959, IS 71633, IS 71683-1, G 40-1, G 54, G 73, G 102, G 116, G 116-1-1, G 131, G 151, G 163, G 164, G 175, G 169, S 437, S 490, S 500-1
2	Days to 50% flowering	278	49.5-98.0	<55	IS 4526, IS 1032, S 520, G 123, G 151, IS 5717, IS 5469, G 45
3	Plant height (cm)	517	43.3-380.0	>320	G 177, G 133, G 161, G 146, G 141, G 199, G 145, Simbhaoli-3, G 185
4	Leaf length (cm)	490	39.0-96.0	>87	G 182, G 178, S 525, G 177, S. roxburghii, G 104-1-2, IS 3042-1, Sweet Sudan-1, SDSL 92111
5	Leaf breadth (cm)	490	2.3-11.5	>9.0	IS 3237-2, Harshpur-3, NRCS 339, Dalpatpur-3, Jaya-3, Simbhaoli-3, Pant Chari 3, Bareilly-4, Hapur-1
6	No. of leaves/plant	517	5.0-53.0	>45	IS 3379, NRCS 177, PL 25, IS 3042-1, IS 5417-2, IS 5469-2, IS 70744-2, IS 3375-1, IS 5469-1
7	Stem girth (cm)	490	2.1-8.5	<2.5	IS 31130, IS 70764, G 195, IS 3275-1, IS 3370, IS 3351, G 189, IS 3214, RSDP 1, IS 3314,
8	No. of tillers/plant	437	1.0-7.4	>5.0	IS 722, IS 3238, SSG 59-3, IS 3042-1, IS 3351, G 148, NRCS 177, S 517, WT-2
9	Leaf stem ratio	208	0.2-1.0	>0.60	IS 6018, Simbhaoli, Bhikhera-1, IS 722, Gajraula-1, Brighat-4, Brighat-3, IS 3313
10	Leaf area index (cm ²)	106	1401.2-8801.6	>6500	SDSL 92113, G 150, G 127, IS 3262, G 146, G 110, S 199, G 143, G 139
11	No. of nodes/plant	106	3.2-10.6	>9.0	S 520, G 143, G 124, S 500, IS 4478, IS 5413, IS 3359, IS 4636, G 46, G 138, IS 14374, IS 1032, IS 1052, IS 4782, IS 10954, G 150, IS 4526, IS 4736, G 140
12	Regeneration potential (%)	106	-49-91.1	>40.0	IS 3234, IS 3228, IS 6018, G 46, G 149, S 184, IS 3075, IS 3359, S 490
13	Growth rate 0-30 DAS	106	1.0-2.6	>2.2	IS 3075, S 500, SDSL 92113, IS 3312, IS 1032, IS 3001, IS 4736, IS 2205, IS 3374, IS 23324, G 45
14	Growth rate 30-45 DAS	106	2.0-6.1	>5.5	S 520, IS 20441, G 127, G 142, IS 3075, IS 23324, IS 70746, IS 4636, IS 23234, G 145, G 151, IS 1032, IS 3374
15	Growth rate 45-60 DAS	106	1.9-7.1	>6.2	G 142, S 184, IS 3075, G 143, G 127, S 518, IS 3262, IS 20441, G 124, G 130, SDSL 92113
16	TSS (Brix %)	154	3.3-16.7	>14.0	APSSVT 10, UPMC 511, JHV 4, SRF 252, IPSSVT 50, J SEL 18, IS 3389
17	Grey leaf spot (score)	146	1.0-5.0	=1.0	IS 651, IS 3075-6, IS 3225, IS 3225-1, IS 3237-2, IS 3266-1, IS 3274, IS 3289, IS 3362, IS 3374, IS 3375-1, IS 5417, IS 5417-1, IS 5417-2, IS 5469, IS 5469-1, IS 5469-2, IS 6014, IS 5717, IS 14374-1, IS 19280, IS 23324, IS 23924, IS 70733, IS 71683, IS 71633-2, G 40-1, G 102, G 110, G 110-1, G 118, S 199, S 375, S 391, S 491, HC 171, HC 308, P 33-1, SDSL 92102-2, SDSL 92116, SDSL 92126-1, SDSL 92134, WT(GP), CSH 13R, S 490, S 437.
18	Zonate leaf spot (score)	146	1.0-3.0	=1.0	IS 651, IS 703, IS 3075-6, IS 3192, IS 3262-1, IS 3274, IS 3289, IS 3313-4, IS 3374, IS 5417-1, IS 5417-2, IS 5469-2, IS 5469-3, IS 5622, IS 5717, IS 14374-1, IS 19280, IS 23924, IS 70733, G 40-1, G 102, G 118, S 199, S 375, S 500, P 33-1, SDSL 92102-2, SDSL 92134, CSH 13R, S 437
19	Sooty stripe (score)	146	1.0-3.7	=1.0	IS 722, IS 1032, IS 1052, IS 2011, IS 3001, IS 3074, IS 3074-1, IS 3075, IS 3075-1, IS 3075-2, IS 3075-3, IS 3203-2, IS 3218, IS 3228, IS 3228-2, IS 3234, IS 3234-1, IS 3234-2, IS 3237-1, IS 3262-1, IS 3275, IS 3275-1, IS 3275-2, IS 3289, IS 3304, IS 3312, IS 3313, IS 3313-4, IS 3359, IS 3365, IS 3374-2, IS 3374-3, IS 3389, IS 4275, IS 4478, IS 4526, IS 4636, IS 4718, IS 4735, IS 4736, IS 4782, IS 5469-3, IS 4725, IS 5622, IS 10954, IS 23924, IS 23959, IS 71683-1, G 45, G 46-1, G 48, G 71, G 97, G 104-1, G 116-1, S 491-1-1, SSG 59-3, R 472, SDSL 92101, WTM-1, WTM-2
20	Stem borer (score)	291	5-Jan	=1.0	IS 722, IS 1005, IS 2483, IS 3152, IS 3214, IS 3234-1, IS 3318, IS 3365, IS 3370, IS 3389, IS 3679, IS 19280, IS 20441, IS 20441-1, IS 21891, IS 23324, IS 70764, IS 71691, ICSV 5469, ICSV 93091, G 76, G 118-1, G 121, G 124, G 135, G 172, NRCS 179, NRCS 198, NRCS 297, S 184, S 510, S 519, S. roxburghii, Sweet Sudan, P 33-5, R 152, R 565, RSDP-1, RS 123, SDSL 92101, SDSL 92134, S 490, S 437
21	GFY/plant (g)	271	36.1-2500	>1500	IS 3375-1, NRCS 198, SDSL 92126-2-1, S 491, IS 70746-1, IS 3275-1, S 375, S 517, G 46-1, NRCS 179, IS 703-1
22	DFY/plant (g)	224	6.1-473.5	>120	IS 3312, IS 3313, S 199, Huzur Gurdar, G 139, G 144, IS 23324, IS 10954, G 84

where, 1 = no symptoms, 2 = few scattered lesions/spots, 3 = typical lesions developed on leaves covering up to 25% leaf area, 4 = coalescing spots covering about 26-40% leaf area, and 5 = symptoms severe, covering more than 40% of leaf area. For stem borer (*Chilo partellus*), scoring was done at 35 and 45 days after germination on leaf feeding using 1-5 scale, where, 1 = no leaf damage, 2 = 1-10% of plants with one or more leaves damaged, 3 = 11-25% of plants with one or more leaves damaged, 4 = 26-40% of plants with one or more leaves damaged, and 5 = >40% of plants with one or more leaves damaged.

Results and Discussion

Range, number of genotypes studied and top ranking genotypes for different characters are presented in Table 1. Figure 1 depicts the means, standard deviation and frequency distribution of different genotypes for various characters in forage sorghum. The perusal of Table 1 and Figure 1 revealed a wide range of variability for all the characters studied. Maximum variability was observed for days to 50% flowering followed by leaf area index, leaf length, leaves per plant, plant height, regeneration potential, TSS, green fodder yield and dry fodder yield per plant. In grain sorghum numerous studies were conducted to judge the variability. The studies indicated presence of enough variability for various characters in forage sorghum (Kang and Lee 1996, Teshome *et al.* 1997; Greneir *et al.* 2000). Similar exhaustive studies in forage sorghum germplasm were also undertaken by Mathur *et al.* (1991 and 1992), Grewal *et al.* (1996) and Yadav *et al.* (2002, 2003 and 2004).

In forage sorghum, germplasm available in the form of multitudes of lines needs critical evaluation for choice of parents in any breeding programme, particularly if the aim is to improve complex quantitative traits. Such work becomes easier if the available germplasm is evaluated on the basis of a given set of characters and then pick up the parents for hybridization either to exploit heterosis or for getting transgressive segregants (Bhatt, 1970; Chandra, 1977; Singh and Gupta, 1979). Lines showing better performance for five or more characters and are extracted from the germplasm evaluated in the present study are given in Table 2. Depending on the objectives of the breeding programme, genotypes from Table 1 and 2 can be selected and further utilized for forage sorghum improvement programme. Considering different aspects of the current and future emphatic areas these germplasm resources can be exploited to tap the fodder yielding

Table 2. Promising genotypes for cluster of traits

Genotype	Character
IS 722	NL, NT, LS, SS, SB
IS 1032	DF, NN, G1, G2, SS
IS 3262	LAI, G3, TSS, ZLS, SS
IS 3313	LS, R, ZLS, SS, DFY
IS 3359	NN, R, G2, TSS, SS
IS 3374	G1, G2, GLS, ZLS, SS
IS 3375-1	NL, NT, GLS, GFY
IS 4478	EV, LS, NN, R, G1, G2, SS
IS 4526	EV, DF, NN, G3, SS
IS 4636	EV, NN, G1, G2, SS
IS 4736	EV, DF, NN, G1, SS
IS 5469	DF, NL, NT, LS, R, GLS, ZLS, SS
IS 23324	EV, G1, G2, G3, GLS, SB, DFY
G 40-1	EV, NL, NT, GLS, ZLS
G 46	NN, R, SS, GFY
G 124	DF, PH, NT, LAI, TSS, DFY
G 127	DF, NT, LS, LAI, G2, G3, TSS, DFY
G 143	DF, LAI, NN, G3, DFY
G 146	DF, PH, NT, LAI, TSS, DFY
G 151	EV, DF, LAI, G2, G3
S 184	DF, R, G2, G3, SB
SDSL 92134	GLS, ZLS, SB, GFY

NT-Number of tillers/plant; LS- Leaf:stem ratio; LAI- Leaf area index; NN- Number of nodes/plant; EV-Early vigour; DF- Days to 50% flowering; PH- Plant height; NL- Number of leaves/plant; R- Regeneration potential; G1, G2, G3- Growth rates (0-30, 30-45 and 45-60 DAS, respectively); TSS- Brix %; GLS- Grey leaf spot; ZLS- Zonate leaf spot; SS- Sooty stripe; SB- Stem borer; GFY- Green fodder yield/plant and DFY- Dry fodder yield/plant.

potential and for improvement and exploitation of other traits in forage sorghums.

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Fig. 1: The means, standard deviation and frequency distribution in genotypes for different characters

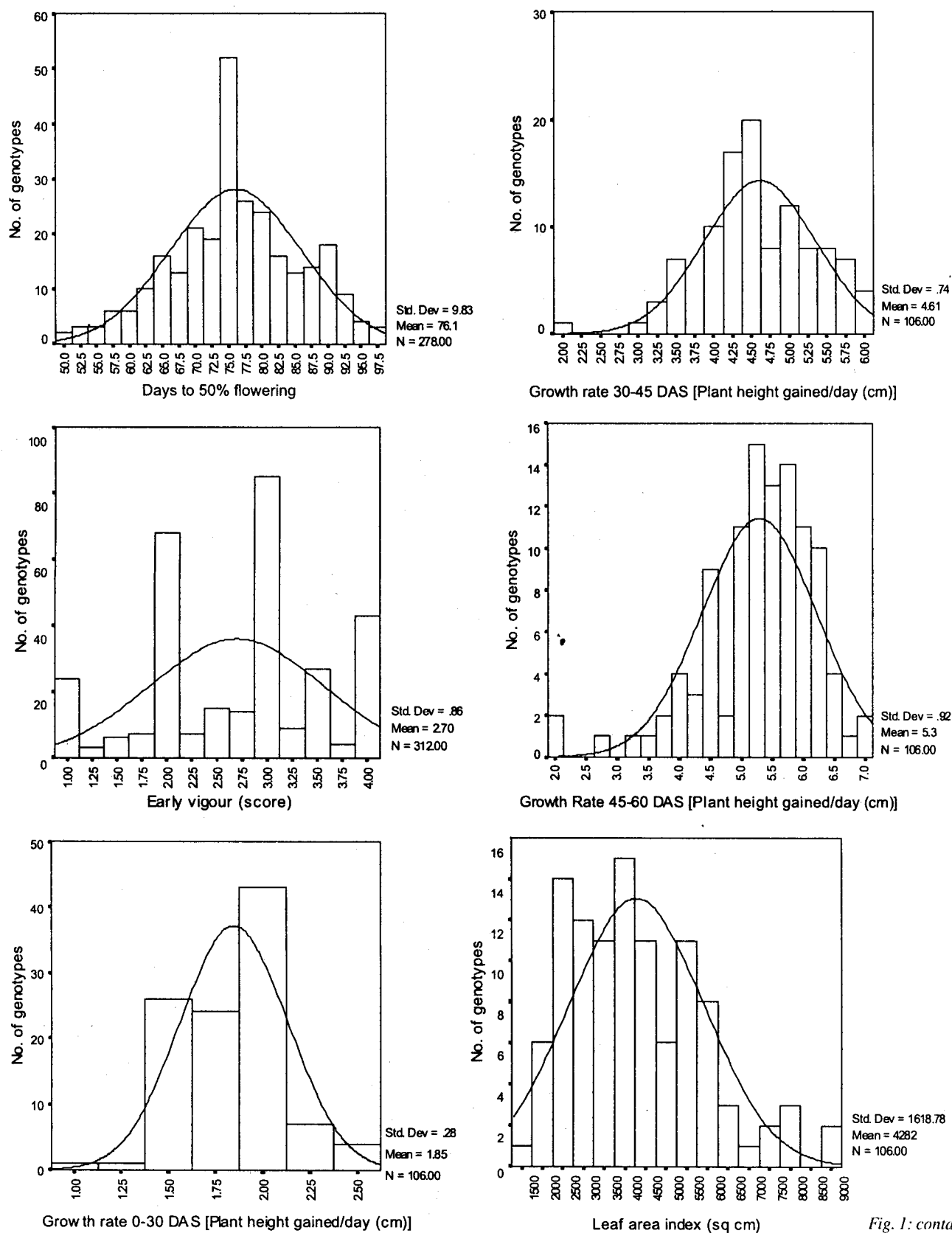


Fig. 1: contd.

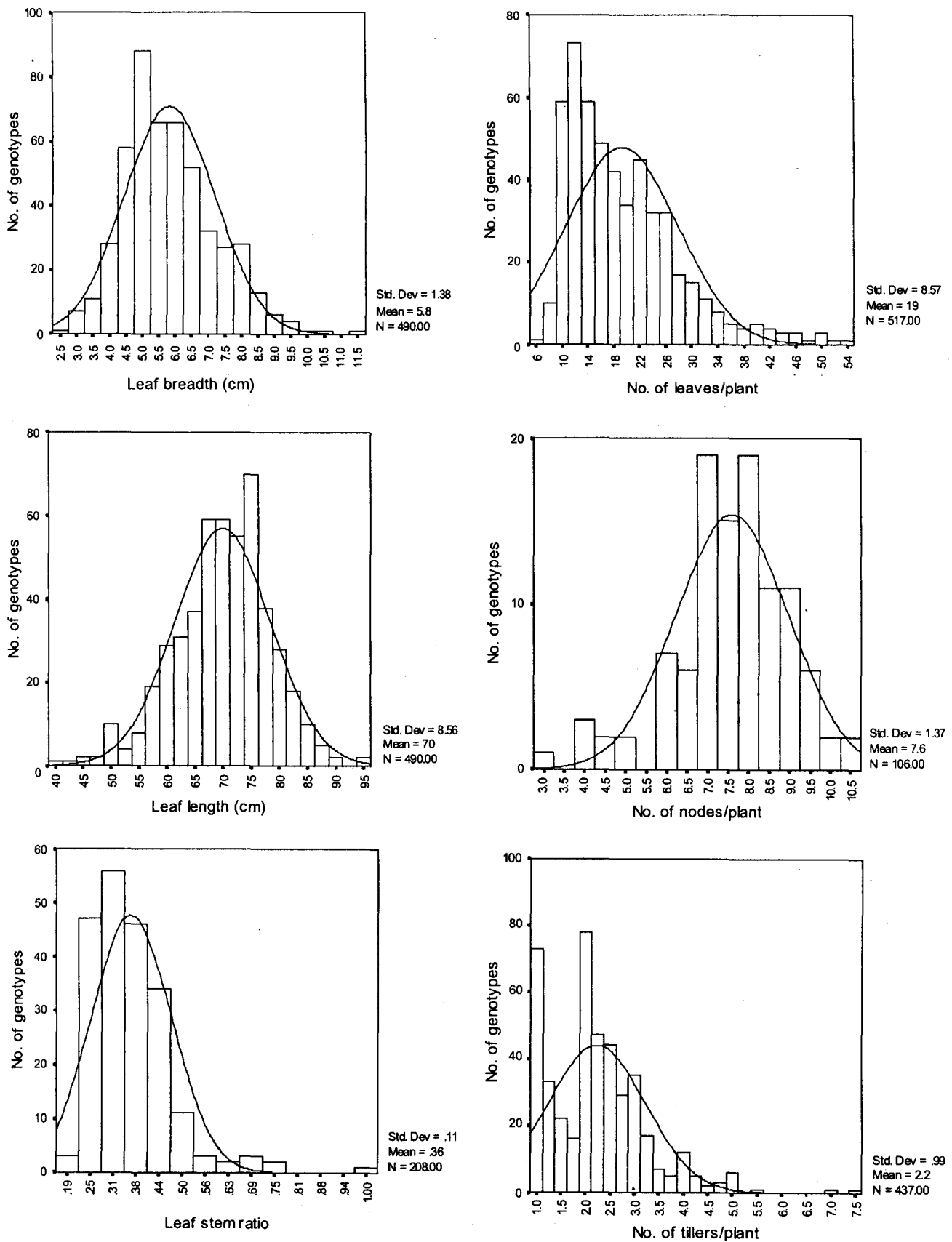


Fig. 1: contd.

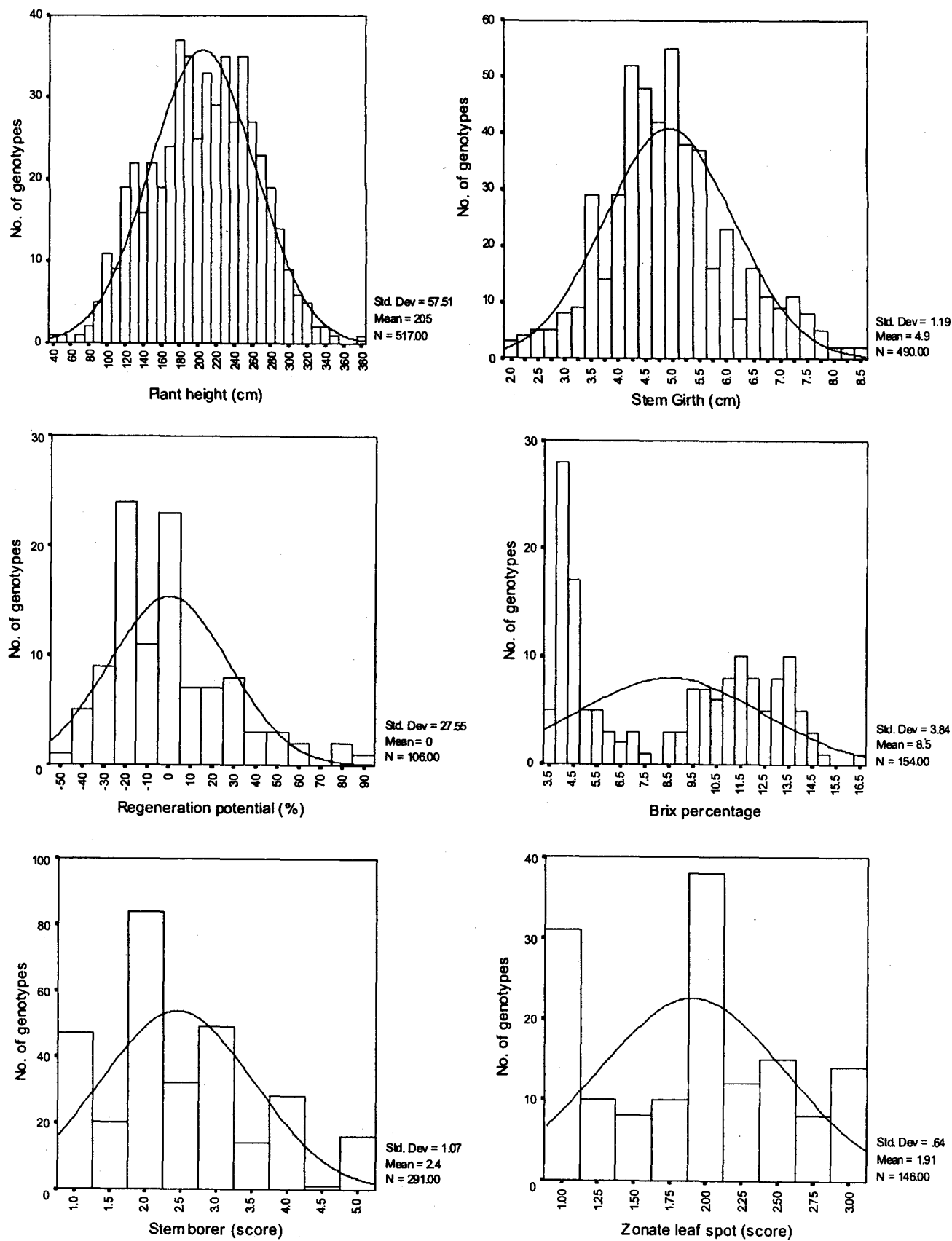
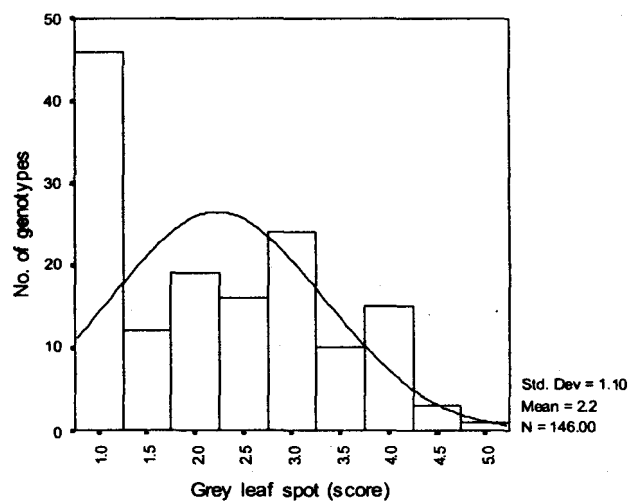
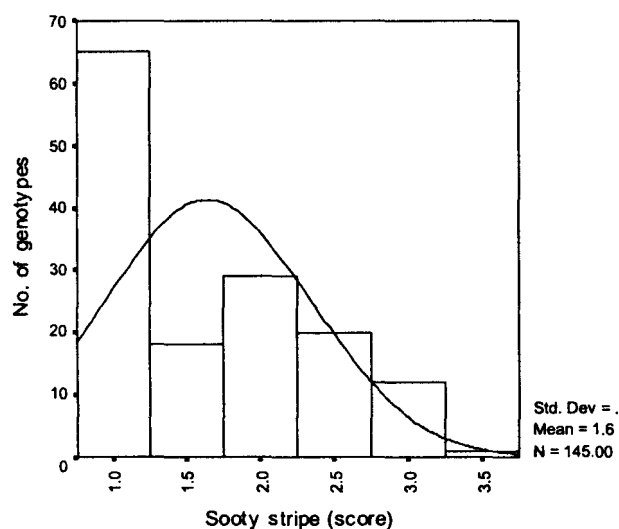
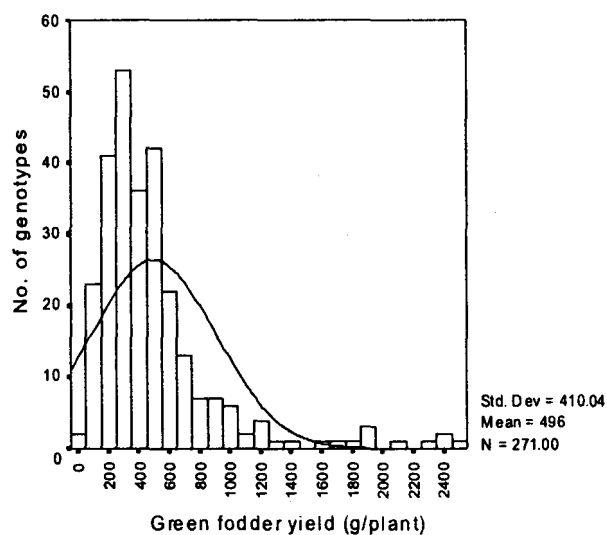
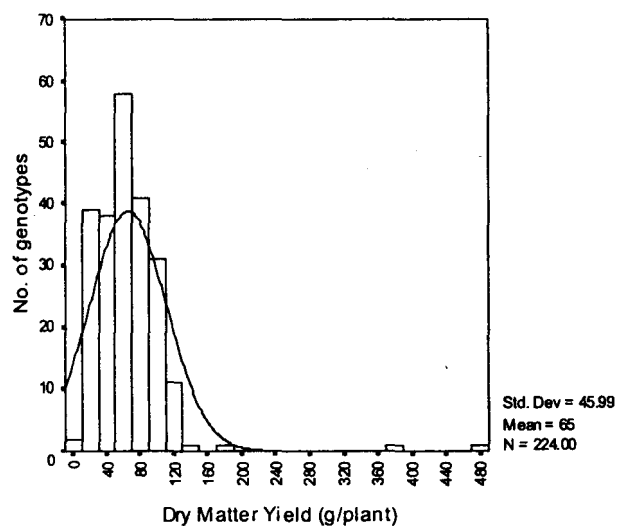


Fig. 1: contd.



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Exploring the Use of Low Temperatures for Enhancing Life Span of Seed Germplasm in Okra

SD Doijode

Division of Plant Genetic Resources, Indian Institute of Horticultural Research, Bangalore-560 089 (Karnataka)

Okra seed germplasm was conserved in moisture semi-permeable and impermeable containers at low (5°C) and sub-zero temperatures (-20°C) for 20 years with the view to ascertain the extent of recovery of germplasm. High seed quality and vigour was obtained both at 5 and -20°C after 20 years of storage. However, the initial viability (96%) was reduced to almost 1/3 (26%) after 5 years of storage at ambient temperature (16-35°C) while it was retained cent per cent for 20 years at low temperature. The okra seed germplasm could be conserved at 5°C in moisture semi-permeable or impermeable containers with the greater extent of recovery. The former appears to be cheaper and easily accessible and also effective for conservation of okra seed germplasm.

Key words: Okra, Conservation, Longevity, Seed germplasm, Storage, Temperature, Viability, Vigour

Okra (*Abelmoschus esculentus* Moench) is widely cultivated vegetable crop in tropics and sub-tropics. Fresh green and immature fruits are used for culinary purposes. Plant shows large variations for morphological traits in different genotypes. The rich diversity is useful for the survival of plant under heterogeneous environment and also for evolving superior genotypes by combining desired genes. As a result more and more areas are brought under high yielding types thereby eliminating some of the heterogeneous varieties and landraces, which might be carrying valuable genes that may prove to be useful in near future. Seeds constitute an important component of plant propagation as well as means of genetic conservation. They preserve well for fairly longer period in other vegetable crops (Doijode, 2001, 2002). Frequent growing of large number of germplasm accessions is labourious and cumbersome and also prone to genetic drift. Thus, there is need to conserve the germplasm for longer period without altering its genetic makeup. Seed as a living entity cannot be kept alive indefinitely, eventually leading to deterioration and loss of the viability (Harrington, 1972). The process of seed deterioration is regulated by the storage conditions (Bass, 1980). Information on extent of recovery of seed germplasm in a given period and protection by rejuvenating in field is lacking in okra. Hence an experiment was conducted with the view to determine optimal conditions for long-term storage as well as to generate information on extent of recovery of germplasm possible in a given period.

Materials and Methods

Seeds of cv Pusa Sawani were used for long-term storage. The initial seed moisture content was 8.3 per cent and seeds were packed in moisture semi-permeable

(Polyethylene bags, 3 mil) and impermeable (Laminated aluminium foil pouches) containers and stored at low (5°C and 40% RH) and sub-zero (-20°C and 85% RH) temperatures for 20 years. Seed quality in terms of viability and vigour was determined periodically. Seed viability was expressed in terms of percentage of germination and they were suitably germinated at an alternate temperature of 20-30°C for 16 and 8 hours respectively. Normal seedlings were used for recording germination percentage. Seedling length was recorded on one week old seedling. Dry weight was recorded on seedling dried at 65°C for 48 hours. The growth parameters were used for comparing vigour (Mugnishah and Nakamura, 1986). The data was statistically analysed for variance and means were compared by using protected least significant difference test at 0.05 probability level.

Results and Discussion

Okra seeds are fairly good storer both at ambient and low temperature storage. The percentage of seed germination was reduced to 44 in semi-permeable and 26 in moisture impermeable containers after 5 years of storage under ambient (16-35°C) temperature. The reduction in germination in moisture impermeable containers might be owing to release and accumulation of excess moisture inside the container during oxidative process (Justice and Bass, 1978). Further, process of deterioration is escalated under higher temperature. Seed storage in polyethylene bags is effective under dry conditions (Villareal *et al.*, 1972). At low temperature storage, seed retained the initial viability for 20 years both at 5 and -20°C (Figure 1).

There was no damage to seeds by chilling at sub-zero temperatures. The deterioration process is minimal

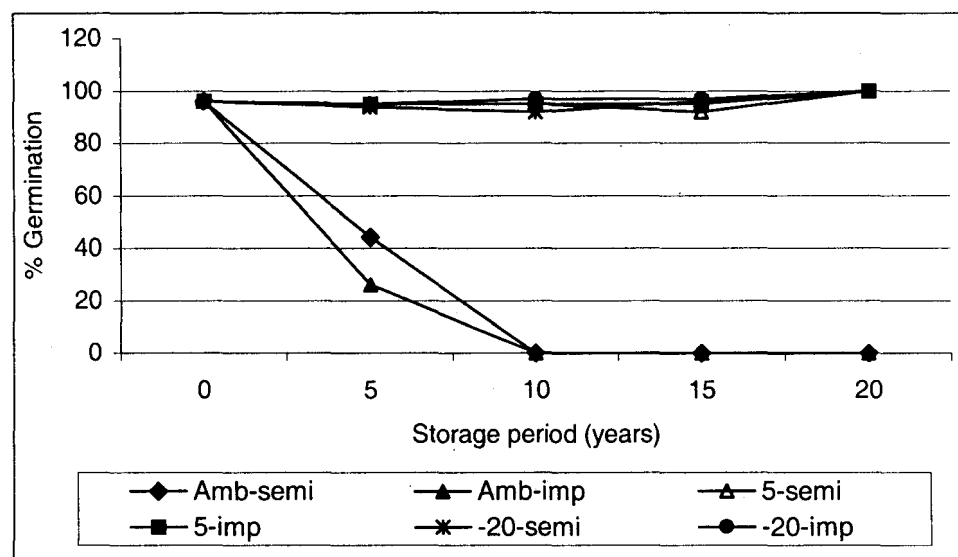


Fig. 1. Long-term conservation in okra

both in moisture semi- and impermeable containers at 5 and -20°C storage. Seeds stored at higher temperature deteriorate faster and showed lower germination and lower seedling vigour (Fonseca *et al.*, 1980). The process of seed deterioration is slower at cooler temperatures (Harrington, 1972). The plants raised from stored seeds were normal and did not exhibit any morphological variations.

The seedling vigour was also preserved well during long-term conservation. High vigour in terms of coefficient of germination, seedling growth, dry weight and vigour was observed seeds stored in low temperature (Table 1).

as for 20 years in okra. It avoids repetitive growing of crop in field and makes lesser dependence on seed banks for supply of seed germplasm. Breeder himself can also preserve seed germplasm in polyethylene bags at 5°C for the present and future usage in crop improvement programme. Seed storage at sub-zero temperature is no doubt an ideal condition for conservation, but at the same time similar extent of recovery of seed germplasm is possible at low temperature (5°C) after 20 years of storage with lesser cost of operation and maintenance. Thus it is advantageous in terms of easy access, economics and effective means to conserve seed germplasm at 5°C for 20 years in okra.

Table 1. Seedling characteristics of stored seed germplasm for 20 years

Storage Temperature ($^{\circ}\text{C}$)	Type of storage containers	Coeff. of Germination (%)	Shoot length (cm)	Root length (cm)	Dry wt. (mg)	Vigour
5	Moist-semi	56.4	13.7	7.6	16.9	61.3
	Moist-imp	55.7	13.8	8.2	16.2	60.3
-20	Moist-semi	69.0	13.9	6.7	14.7	77.3
	Moist-imp	55.1	12.3	8.7	17.7	59.3
CD at 5%		3.6	0.9	NS	1.6	4.0

The results confirmed that low temperature storage is effective in maintaining high viability and vigour of stored seed germplasm in okra. In this, moisture semi and impermeable containers could be used successfully for conservation of seeds for 20 years and the deterioration was minimal both at 5 and -20°C . The former could be employed in view of easy accessibility as well as highly cost effective for maintenance of high quality as long

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An Improved Method of Analysis of Glycyrrhizic Acid in Mulethi (*Glycyrrhiza glabra* L.)

CS Raghav, Poonam Suneja and MA Kidwai

National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi-110 012

An improved technique for the estimation of glycyrrhizic acid has been developed in *Glycyrrhiza glabra* L. The technique is based on the estimation of glycyrrhizic acid through its aglycone, the glycyrrhetic acid. The procedure reported so far give erroneous results because of the fact that the amount of non-glycyrrhizic acid components accompanying glycyrrhizic acid were not taken into consideration during the processing of samples. This method is considered to be more accurate as it also estimates the glycyrrhizic acid present during the preliminary processing of samples i.e. filtration and washings etc.

Key words: Mulethi, *Glycyrrhiza glabra*, Chemical analysis

Roots of *Glycyrrhiza glabra* L. and their aqueous extracts and formulation are extensively used in medicine (Brown and Dattner 1998). The active principle responsible for biological activity is glycyrrhizic acid, an acidic saponin. It is present in roots as calcium or potassium salts, known as glycyrrhizin along with fats, sterols, flavonoids, carbohydrates etc. A number of procedures have been reported for the extraction, isolation and estimation of glycyrrhizin and glycyrrhizic acid (Gou *et al.*, 1999, Lay *et al.*, 2000, Lee *et al.*, 1995, Tsai and Chen, 1991). Most of them are based on the solubility of glycyrrhizin in water, precipitation of glycyrrhizic acid with dilute mineral acid followed by conversion of the acid into its ammonium salts. Generally, it has been observed that the extraction is carried out either by dilute alcohol or water. None of these procedures have proved to be very accurate for quantitative determination for quality assay.

The erroneous results may be due to the loss of glycyrrhizin during the course of extraction with water or dilute alcohol. The glycyrrhizic acid is soluble in water and is lost during the initial processing, i.e., washings and filtration of the samples. Earlier, an attempt has been made to estimate it through glycyrrhetic acid by using charcoal, but with little success. About three per cent glycyrrhetic acid is reported to be lost during the course of estimation. It has also been found that precipitated glycyrrhizic acid contained small amount of neutral, phenolic and solvent insoluble matter, which add to the inaccuracy of such procedures. In view of the necessity of an accurate estimation procedure for the quality assay of the samples, an improved method has been developed to hydrolyse glycyrrhizin to glycyrrhetic acid with dilute sulphuric acid.

Materials and Methods

Following steps were conducted to estimate the glycyrrhizic acid and glycyrrhetic acid from the roots of *Glycyrrhiza glabra*.

Isolation and purification of glycyrrhizic acid and extent of hydrolysis of glycyrrhizic acid to glycyrrhetic acid

The powdered root sample of *Glycyrrhiza glabra* was extracted with methanol. The glycyrrhizic acid was isolated from the water soluble part of the methanolic extract by precipitation with hydrochloric acid. The glycyrrhizic acid was purified by converting it into its ammonium salt and re-precipitated by using hydrochloric acid. More than 99 per cent glycyrrhetic acid was obtained by hydrolyzing glycyrrhizic acid, so obtained using 10 per cent sulphuric acid.

Extraction, isolation and estimation of glycyrrhizic acid by precipitation method

Ten gram of dried and powdered roots were extracted by continuous hot extraction in Soxhlet's apparatus with methanol for six hours. Methanol was then distilled off under vacuum. The flask and filter paper were washed thrice with distilled water and make up the volume up to 15 ml. The combined aqueous extract was then cooled to 4-6° C and treated with cold 1 per cent sulphuric acid. The glycyrrhizic acid was dissolved in methanol and filtered. The filtrate was transferred to a previously weighed evaporating dish. Methanol was evaporated on a gently boiling water bath and the glycyrrhizic acid left behind was dried in oven at 100-105° C till constant weight (Table 1).

Table 1. Glycyrrhizic acid analysis by precipitation method

Accessions	Glycyrrhizic acid (g)	Glycyrrhizic acid (%)
EC2708	0.5964	5.964
EC19741	0.3790	3.790
EC25371	0.5148	5.148
EC21950	0.4504	4.504
EC25967	0.4694	4.694
EC25409	0.4208	4.208

Isolation of glycyrrhetic acid, neutral, phenolic and solvent insoluble matter from the precipitated glycyrrhizic acid

The glycyrrhizic acid so obtained was hydrolysed with 10 per cent sulphuric acid. The hydrolysed products were extracted with ether. The ethereal extract was washed with 5 per cent potassium hydroxide solution leaving behind only non acidic substances in ether. The potassium hydroxide extract was acidified and extracted with ether to get glycyrrhetic acid and phenolic substances. These were then acetylated which made it possible to separate glycyrrhetic acid from phenolic substances. Insoluble organic matter was separated earlier from precipitated glycyrrhizic acid by dissolving it in methanol and filtration (Table 2).

The filtrate and washings from the precipitated glycyrrhizic acid were collected and hydrolysed with 10 per cent sulphuric acid. Glycyrrhetic acid was then separated according to the same procedure used earlier. The acid thus obtained was dried to constant weight. The corresponding amount of glycyrrhizic acid was found out and its percentage calculated (Table 3).

Isolation of glycyrrhetic acid from the hydrolysis product of root extract and estimation of glycyrrhizic acid

The methanolic extract of the roots was dissolved in 10 ml. water and filtered. The filtrate and the flask were washed thrice with distilled water (15 ml). The filtrate containing glycyrrhizin was then hydrolysed with 10 per cent sulphuric acid. Glycyrrhetic acid along with phenolic

and neutral substance was extracted with ether from the hydrolysis products. It was then acetylated with acetic anhydride-toluene and pure glycyrrhetic acid was separated from the phenolic and neutral substances. Corresponding amount of glycyrrhizic acid was then calculated from the amount of glycyrrhetic acid thus obtained and the percentage of glycyrrhizic acid was determined (Table 4).

The water soluble part of the methanolic extract of the root was hydrolysed with 10 per cent sulphuric acid and the hydrolysis product extracted with ether and acetylated. Glycyrrhetic acid was then separated from neutral and phenolic substances in one stage. The amount of glycyrrhizic acid corresponding to glycyrrhetic acid was found out and the percentage of glycyrrhizic acid was calculated from the formula:

$$\text{Per cent glycyrrhizic acid} = \frac{AB}{C} \times 100/D$$

Where, A is the molecular weight of glycyrrhizic acid; B, the weight of glycyrrhetic acid obtained; C, the molecular weight of glycyrrhetic acid, and D, the weight of powdered roots.

Results and Discussion

The above data showed that the yield of glycyrrhetic acid was over 99 per cent. The percentage of glycyrrhizic acid in various samples by precipitation method is given in Table 1, whereas, Table 2 contains the data which bring about interesting observations and results. The precipitated glycyrrhizic acid on hydrolysis yields glycyrrhetic acid, neutral and phenolic substances in addition to a small

Table 2. Determination of Glycyrrhizic acid, neutral, phenolic and solvent insoluble matter in precipitated glycyrrhizic acid

Accessions	Glycyrrhizic acid obtained (g)	Glycyrrhizic acid (%)	Glycyrrhetic acid from glycyrrhizic acid	Phenolic and neutral matter in glycyrrhizic (g)	Solvent insoluble matter in glycyrrhizic acid (g)	Glycyrrhizic acid corresponding to glycyrrhetic (g)	Glycyrrhizic acid in precipitated glycyrrhetic acid (g)(%)
EC 2708	0.5964	5.964	0.3166	3.28	3.86	0.5537	92.84
EC 19741	0.3790	3.790	0.2033	2.64	3.52	0.3555	93.80
EC 25371	0.5148	5.148	0.2802	2.21	2.60	0.4900	95.19
EC 21950	0.4504	4.504	0.2398	3.09	3.77	0.4194	93.12
EC 25967	0.4694	4.694	0.2470	3.62	4.36	0.4319	92.02
EC 25409	0.4208	4.208	0.2234	3.33	3.80	0.3907	92.85

Table 3. Determination of glycyrrhizic acid from precipitated glycyrrhizic acid during preliminary processing

Accession Nos.	Glycyrrhizic acid in precipitated glycyrrhizic acid	Glycyrrhetic acid from the filtrate	Glycyrrhizic acid corresponding to glycyrrhetic acid (g)	Total Glycyrrhizic acid (g)	Glycyrrhizic acid in the filtrate (%)
EC 2708	0.5537	0.0630	0.1101	0.6638	16.58
EC 19741	0.3555	0.618	0.1080	0.4635	23.30
EC 25371	0.4900	0.628	0.1098	0.5998	18.13
EC 21950	0.4194	0.0609	0.1065	0.5259	20.25
EC 25967	0.4319	0.0619	0.1080	0.5399	20.00

Table 4. Estimation of glycyrrhizic acid through glycyrrhetic acid

Accessions	Glycyrrhizic acid (g)	Glycyrrhizic acid corresponding to glycyrrhetic acid (g)	Glycyrrhizic acid (g)
EC2708	0.3790	0.6628	6.628
EC19741	0.2633	0.4605	4.605
EC25371	0.3422	0.5984	5.984
EC21950	0.2978	0.5208	5.208
EC25967	0.3091	0.5406	5.406
EC25409	0.2822	0.4935	4.935

amount of solvent insoluble organic matter obtained on dissolving glycyrrhizic acid in methanol. It is evident from the data that 92.02 to 95.19 per cent of pure glycyrrhizic acid was recovered.

The solubility of glycyrrhizic acid in water and the extent to which it lost during filtration and washing is presented in Table 3. The amount of glycyrrhetic acid obtained from the filtrate and washings correspond to the amount of glycyrrhizic acid to the extent from 16.58 to 23.30 per cent which was lost during the course of filtration and washing. Table 4 shows the data related to estimation of glycyrrhizic acid through glycyrrhetic acid.

The amount of glycyrrhizic acid thus obtained is almost equal to the sum of the glycyrrhizic acid present

in the precipitated glycyrrhizic acid and in the filtrate and washings thus providing more accurate and reproducible results. This technique provides more accuracy and reproducibility. It is of immense value in the quality assay of mulethi samples where an even minor difference in the glycyrrhizic acid content plays very important role.

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SHORT COMMUNICATION

Genetic Variability for Quality and Metric Traits and its Contribution to Yield in Barley (*Hordeum vulgare* L.)

DS Pilonia¹ and RPS Dhaka²

¹ National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi-110 012

² Ex-Principal, Kisan Post Graduate College, Simbhaoli, Ghaziabad (Uttar Pradesh)

Key words: Heritability, Genetic advance, Morphological characterization, *Hordeum vulgare* L.

The barley (*Hordeum vulgare* L.) is cultivated under varied agro-climatic conditions and it is world's fourth most important cereal after wheat, maize and rice. There is need to identify and characterize the varieties/ genotypes suitable under varied agro-climatic conditions and fertility levels. Genetic variability present in a crop is more useful to a plant breeder for exploitation in selection or hybridization.

The experiment was conducted to evaluate diverse genetic populations and select the elite genotypes under different level of fertilizer and irrigation. The genetic parameters like, variability, heritability and genetic advance plays an important role in evaluating the material for desirable traits. Therefore, present investigation was undertaken to assess different parameters of variability, heritability and genetic advance.

The experimental material comprised of 35 diverse genotypes of barley obtained from the Director, National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi. The material was grown in a Randomized Block Design with three replications at experimental farm of Kisan Post Graduate College, Simbhaoli, Ghaziabad (U.P.), India during rabi season of 1997-98 and 1998-99 under two levels of each fertilizer and irrigation (Table 1). The standard packages of agronomic practices for raising a good crop were followed. The observations were recorded on three randomly selected competitive plants from each genotypes on eleven morphological traits viz., days to flowering, days to maturity, plant height (cm), tillers per plant, ear length (cm), spikelets per ear, seeds per spike, grain yield per plant (g), 1000 grain weight (g), biological yield per plant (g) and harvest index (%) and two quality traits malt percentage and starch percentage. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were computed followed by Burton and De Vane (1953) while heritability and genetic advance were calculated as suggested by Allard (1960) for all the characters under study.

Table 1. Details of environments in the years 1997-98 and 1998-99

Fertilizer levels	Irrigations	Environments
1997-98		
40 kg N ₂ 20 kg P ₂ O ₅ 20 kg K ₂ O	One	I
40 kg N ₂ 20 kg P ₂ O ₅ 20 kg K ₂ O	Three	II
20 kg N ₂ 20 kg P ₂ O ₅ 20 kg K ₂ O	One	III
20 kg N ₂ 20 kg P ₂ O ₅ 20 kg K ₂ O	Three	IV
1998-99		
40 kg N ₂ 20 kg P ₂ O ₅ 20 kg K ₂ O	One	V
40 kg N ₂ 20 kg P ₂ O ₅ 20 kg K ₂ O	Three	VI
20 kg N ₂ 20 kg P ₂ O ₅ 20 kg K ₂ O	One	VII
20 kg N ₂ 20 kg P ₂ O ₅ 20 kg K ₂ O	Three	VIII

The Analysis of Variance (ANOVA) for 13 traits of 35 genotypes of barley for the two years is given in Table 2. ANOVA revealed that the mean sum of square (MSS) due to treatment is significant for all the thirteen traits under all the eight environments studies, except days to maturity in II and VI environments. It indicates that considerable genotypic variability exists amongst the genotypes. Similar results have also been reported by Yadav *et al.* (1991) and Ram Kishor *et al.* (2000).

Table 2. ANOVA for different characters in different environments-(i-viii)

Source	d.f.	Days to flowering	Days to maturity	Plant height (cm)	Tiller no. per plant	Ear length (cm)	No. of spikelets per ear	No. of seeds per spike	Grain yield per plant(g)	1000 grain wt. (g)	Biological yield per plant (g)	Harvest index (%)	Malt (%)	Starch (%)
Environment-I														
Replication	2	19.37	52.00	-0.12	0.26	1.12	28.65	0.34	0.10	1.95	0.64	3.86	516.34	270.54
Treatment	34	41.82**	38.19**	48.97**	5.71**	0.30**	82.50**	71.82**	3.21**	18.45**	21.59**	59.36**	15.35**	7.52**
Error	68	9.61	18.57	14.42	8.73	9.32	4.88	4.06	0.13	0.90	0.82	4.45	0.83	0.51
Environment-II														
Replication	2	1.06	10.00	1.43	0.34	4.73	17.04	0.00	0.54	1.63	7.81	3.51	507.00	304.10
Treatment	34	32.84**	21.37	51.96**	6.59**	0.33**	82.67**	62.58**	3.29**	17.14**	18.44**	62.73**	15.63**	6.29**
Error	68	11.83	20.37	15.42	0.13	0.10	5.32	4.39	0.18	0.96	0.99	1.51	0.81	0.48
Environment-III														
Replication	2	11.75	7.00	13.75	3.22	9.08	1.96	3.59	6.59	1.68	8.20	0.24	462.65	261.51
Treatment	34	26.67**	44.59**	39.20**	4.09**	0.70**	74.13**	60.49**	3.64**	15.83**	18.78**	59.00**	15.96**	3.56**
Error	68	10.48	17.88	14.02	7.87	8.48	4.60	3.53	0.11	0.87	0.73	0.22	0.67	0.42
Environment-IV														
Replication	2	4.15	20.75	7.43	8.78	4.56	4.07	1.53	0.11	0.37	0.32	0.15	50.03	302.9
Treatment	34	33.76**	37.24**	40.28**	4.81**	0.49**	111.11**	67.61**	3.99**	15.42**	18.63**	64.55**	16.15**	42.06**
Error	68	10.67	19.36	14.57	0.11	9.28	4.08	3.81	0.13	0.93	0.83	0.13	0.87	0.48
Environment-V														
Replication	2	11.68	43.50	1.75	0.25	2.24	32.71	0.59	1.61	0.42	2.42	2.64	310.68	166.68
Treatment	34	36.75**	35.20**	52.02**	5.88**	0.37**	84.89**	69.74**	3.45**	18.75**	19.88**	59.80**	22.43**	6.85**
Error	68	9.47	17.07	16.72	8.89	9.84	5.35	3.80	0.23	0.85	1.27	5.09	4.06	4.52
Environment-VI														
Replication	2	1.90	4.31	1.56	0.24	53.71	24.42	0.85	0.68	1.87	0.21	5.74	369.06	239.32
Treatment	34	30.54**	21.74	46.90**	6.64**	0.34**	84.28**	62.85**	3.34**	17.31**	17.58**	69.12**	13.71**	5.65**
Error	68	13.65	18.17	16.92	0.14	0.10	7.01	5.13	0.17	0.94	1.18	2.37	4.20	1.52
Environment-VII														
Replication	2	42.59	5.12	6.68	8.30	0.15	4.98	4.31	5.51	2.60	9.37	4.73	364.81	287.17
Treatment	34	27.78**	39.96**	33.05**	4.03**	0.70**	66.09**	60.35**	3.80**	16.92**	18.87**	57.25**	15.15**	4.10*
Error	68	9.56	14.74	15.05	9.78	8.52	5.83	3.75	0.13	0.88	1.20	1.68	2.08	0.74
Environment-VIII														
Replication	2	10.25	23.06	6.06	0.11	4.34	4.14	2.28	0.11	0.48	0.46	0.14	431.12	289.35
Treatment	34	33.78**	34.37**	45.73**	5.14**	0.49**	119.35**	64.31**	4.00**	14.78**	17.64**	74.37**	14.79**	41.44**
Error	68	11.61	18.17	17.74	0.12	9.60	4.08	4.47	0.13	0.97	1.06	1.55	1.51	0.52

**Significant at 1% level

The phenotypic coefficient of variation (PCV) is found higher than the corresponding genotypic coefficient of variation (GCV) for all the traits (Table 3) studied. This is because that variability at phenotypic level includes genotypic and environmental variability as earlier reported by Chauhan *et al.* (1988) and Ram Kishor *et al.* (2000). On the basis of pooled analysis, phenotypic coefficient of variation for different traits ranged from 1.77 to 13.10 whereas, genotypic coefficient of variation ranged from 1.07 to 12.64. The high estimates of both PCV and corresponding GCV values for tillers per plant, spikelets per ear, seeds per spike, grain yield per plant, biological yield per plant, 1000 grain weight and harvest index indicate the presence of ample genetic variability in the experimental material for these traits. Similar results were also reported by Chauhan *et al.* (1988), Sharma and Maloo (1994), Sajeda Begum and Khatun. (1997) and Ram Kishor *et al.* (2000). The lowest PCV and GCV values were observed for malt and starch percentage indicating that these traits exhibits low variability which suggests that more variability should be generated for these traits through hybridization or mutation breeding.

Heritability estimates along with genetic advance are more useful in predicting the possible gain under selection. High estimates of heritability, in broad sense, were recorded for tillers per plant, harvest index, grain yield per plant, 1000 grain weight, spikelets per ear, seeds per spike, biological yield per plant, malt percentage and starch percentage. It indicates the high heritable nature of these traits and are less affected by the environments. Therefore, selection should be based on these traits. Sajeda Begum and Khatun. (1997), Kaeppler and Rasmusson (1991),

Yadav *et al.* (1991), Hennawy (1997), Yadav. (1993) and Vimal and Vishwakarma (1998) have also reported high heritability for grain yield/ plant, alpha amylase activity, tillers/plant and grains/spike, 1000-grain wt. and grain yield/plant, respectively. Plant height, days to flowering and ear length exhibited moderate heritability indicating that these traits are more influenced by the environments. Therefore, direct selection for these traits may not be so useful from the genotypes under study.

Heritability and GCV are not sufficient to determine the amount of variation which is heritable from parents to their off springs. Burton and De vane (1953) found that the high heritability estimate alone is of little use in predicting the breeding value of any trait. High heritability coupled with high genetic advance gives an idea of the possible improvement through selection. High heritability coupled with high genetic advance over mean, observed for tillers per plant, biological yield per plant, harvest index, 1000 grain weight, grain yield per plant, seeds per spike and spikelets per ear are given in (Table 3). Therefore, improvement in these traits may be achieved through selection. Malt and starch percentage exhibits low genetic advance with moderate heritability estimates indicating the presence of non-additive gene effects. Therefore, the direct selection for these traits in segregating populations will not contribute for the genetic improvement in yield of barley. High heritability and high genetic advance was also observed by Aidum *et al.* (1990), Vimal and Vishwakarma (1998) and Ram Kishor *et al.* (2000) for tillers/plant, length of spike, number of spikelets/ spike, grain yield/plant, number of seeds/spike, 1000-grain wt. and grain yield/plant, respectively.

Table 3. Estimates of mean, range, phenotypic and genotypic coefficient of variability, heritability and genetic advance on pooled basis

Characters	Mean $\pm$ SEM	Range	PCV	GCV	Heritability	Genetic advance as % of mean
Days to flowering	94.53 $\pm$ 1.31	88.18-100.03	4.64	3.14	45.80	4.37
Days to maturity	124.33 $\pm$ 1.72	117.28-129.12	4.04	2.19	29.30	2.44
Plant height (cm)	109.58 $\pm$ 1.57	103.24-117.02	4.71	3.12	44.00	4.26
Tiller no./plant	9.37 $\pm$ 0.13	7.31-11.83	13.10	12.64	93.10	28.06
Ear length (cm)	8.82 $\pm$ 0.12	8.24-9.57	4.43	2.83	40.90	3.74
Spikelets/ear	62.89 $\pm$ 0.90	51.74-71.60	7.21	6.29	76.20	11.30
Seeds/spike	57.15 $\pm$ 0.80	49.63-67.21	8.01	7.22	81.20	13.40
Grain yield/plant (g)	11.03 $\pm$ 0.15	9.13-12.80	8.54	7.80	83.40	14.68
1000 grain wt. (g)	27.64 $\pm$ 0.38	25.06-31.26	9.00	8.33	85.70	15.88
Biological yield/plant (g)	26.80 $\pm$ 0.39	20.86-38.12	9.30	8.58	85.10	16.30
Harvest index (%)	42.04 $\pm$ 0.55	34.47-48.10	8.90	8.30	87.00	15.93
Malt percentage	80.92 $\pm$ 0.46	77.73-83.88	1.77	1.07	73.72	5.14
Starch percentage	58.69 $\pm$ 0.35	57.17-64.87	1.98	1.32	68.56	5.75

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SHORT COMMUNICATION

Identification of Resistance Source against Shot Hole – A Fungal Disease in Peach (*Prunus persica* L.) Germplasm

VD Verma, SK Sharma*, K Pradheep and JC Rana

National Bureau of Plant Genetic Resources, Regional Station, Phagli, Shimla-171 004 (Himachal Pradesh)

*Indian Agricultural Research Institute, Regional Station, Amartara, Shimla-171 004 (Himachal Pradesh)

Key words: Peach, *Prunus persica*, Shot hole, *Wilsonomyces carpophilus*, *Stigmina* blight, Fruit spot

Shot hole disease of stone fruits caused by a fungus *Wilsonomyces carpophilus* Lev. (Adaskaveg *et al.*, 1990) is an important and widespread disease in North-west Himalayan region. It is also known as Coryneum blight, California peach blight, fruit spot, winter blight and postular spot. The earlier generic names for this fungus include *Clasterosporium*, *Coryneum* and *Stigmina*. In India, Munjal and Kulshrestha (1968) first reported occurrence of this disease on peach, apricot and almond. Shot hole disease has been reported in lower hills of Kullu valley, areas of Mandi, Solan and Shimla districts of Himachal Pradesh (Gupta *et al.*, 1973b).

The fungus of shot hole produces black fruit like fruiting bodies on the necrotic cankers and twigs. The fruiting bodies produce numerous conidia which are thick walled, ellipsoidal or fusiform which infest buds and twigs of trees during winter. Blight symptoms appear on twigs, leaves and fruits. On twigs small purple and slightly raised pustules appear in late December or early January, which later develops into necrotic canker. The spot on fruits are small, circular, deep purple which appear on peach fruits when they attain almost half size in the middle of May. On leaves dark brown, scattered lesions enlarge rapidly and abscission of the diseased area results in shot hole. The intensity of the infestation become severe when the day temperature rises and occurrence of frequent rains for several months from spring to summer (Gupta *et al.*, 1972-1974). Consequent upon, several holes of 0.1 to 0.3 mm of diameter appear on the peach leaves. Owing to shot hole severity the peach leaves becomes sieved, therefore net photosynthetic leaf area is reduces and translocation of photosynthate from leaves to the fruits may be insufficient.

Present investigation was carried out in the peach block of field gene bank, at National Bureau of Plant Genetic Resources, Phagli, Shimla during

rainy season 2005. Peach block containing 38 accessions of 8 to 15 years of age. The observations on reaction to shot hole infestation were recorded during rainy season 2005 on single plant of each accession, when the disease severity was high. Ten randomly selected leaves from all corners of each accession were taken to record number of holes on the leaves. Then average value was considered to determine the level of susceptibility to shot hole based on 1 to 9 scale as per minimal descriptors of peach published by National Bureau of Plant Genetic Resources, New Delhi (Mahajan *et al.*, 2002). Reaction to shot hole disease (Figures 1 and 2) in 38 peach accessions is presented in Table 1. Three accessions of peach *i.e.* IC 209015, IC 349931 and EC 321412 showed very low susceptibility indicating high resistance to shot hole disease. Five accessions *i.e.*, EC 552645, EC 468323, EC 468324, IC 19398 and IC 20841 showed low symptom against shot hole disease, these accessions were rated as resistant. Nine peach accessions showed tolerance, 12 accessions as susceptible and 9 accessions as highly susceptible.

Meagre information is reported about resistant genotypes for shot hole in peach. Simone (1985) has



Fig. 1: Peach (EC38736) susceptible to shot hole

Table 1. Reaction to shot hole disease in 38 peach accessions

S.No	Accession	Alternate identity	Disease score	Remark
EC 321412	Nemaguard	1	highly resistant	
EC 552639	Sun Red	7	susceptible	
EC 38737	Kanto 5	9	highly susceptible	
EC 280769	Yum Yung	9	highly susceptible	
EC 552640	Flordasun	7	susceptible	
EC 552641	Co-Smith	9	highly susceptible	
EC 552642	Snow queen	7	susceptible	
EC 174084	Luna	5	tolerant	
EC 27793	July Elberta	7	susceptible	
EC 38736	Nishiki	9	highly susceptible	
EC 468326	Fortuna	5	tolerant	
EC 552645	Early Red Fair	3	resistant	
EC 27791	Stark Ealy Glo	9	highly susceptible	
EC 552643	Florabella	7	susceptible	
EC 280765	Okubo	5	tolerant	
EC 110858	Stanford	7	susceptible	
EC 312408	May Fair	5	tolerant	
EC 115563	Dixi Red	9	highly susceptible	
EC 280767	Nunomwasi	7	susceptible	
EC 110859	Boyce	5	tolerant	
EC 198817	Summer Glo	9	highly susceptible	
EC 57530	Candor	9	highly susceptible	
EC 313953	Sone peach	7	susceptible	
Red Gold	Red Gold	5	tolerant	
EC 331812	Fire Prince	7	susceptible	
EC 552644	Duke	5	tolerant	
EC 468323	Andross	3	resistant	
EC 468324	Fertilia	3	resistant	
IC 209015	BDJ-341	1	highly resistant	
IC 349931	RSSML-25	1	highly resistant	
IC 349929	RSSML-23	9	highly susceptible	
IC 201914	BDJ-340	7	susceptible	
IC 349928	Shan-e-Panjab	7	susceptible	
IC 349930	S-37	7	susceptible	
IC 19398	BDJ-93-39	3	resistant	
IC 20840	BDJ-188	5	tolerant	
IC 020841	BDJ-206	3	resistant	
IC 19397	BDJ 93-32	5	tolerant	

1: very low or no visible sign of susceptibility; 3: low; 5: intermediate; 7: high; 9: very high

also reported that peach diseases are major production and marketing problems, there have been few reports on significant levels of resistance to most peach infecting

organisms and little information is available about resistance to shot hole (*Stigmia carpophila* (Lev.) Ell. syn. *Coryneum beyerinckii* Oud. Keil and Fogel (1974)

reported that Nemaguard is resistant to bacterial leaf and fruit spot. Ramming and Tanner (1983) reported that Nemaguard a cultivar of peach and its recently released offspring Nemared are the most widely used resistant stocks against nematodes, although Nectared 2 has somewhat resistant to shot hole. Hesse (1975) has also reported that Nemaguard is resistant to root-knot nematode *Meloidogyne incognita* and *M. javanica*. Therefore, the accession EC 321412 (Nemaguard) has dual advantage of resistance for shot hole and nematode as well. EC 321412 (Nemaguard) was introduced at this station from USA during mid eighties, it has large size fruit (average fruit length 62.8mm,



Fig. 2: Peach (IC209015) resistant to shot hole

average fruit width 58.9 mm and average fruit weight 111g) with high productivity status. Other two peach accessions IC 209015 and IC 349931 are indigenous collections showed high level of resistance against shot hole disease have medium size fruits (average fruit weight 66.4g and 49.4g respectively) and productivity status (high and low respectively). These three peach accessions (EC 321412, IC 209015 and IC 349931) can be utilized in crop improvement programme.

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SHORT COMMUNICATION

Distribution and Variation of Mulberry Genetic Resources (*Morus* spp.) in the High Altitude and Cold Deserts of Ladakh Himalayan Region

A Ananda Rao¹, K Thangavelu¹ and KR Sharma²

¹ Central Sericultural Germplasm Resources Centre (CSGRC), Hosur-635 109 (Tamil Nadu)

² Regional Development Office, Central Silk Board, New Delhi-110 012

Key words: Mulberry, Cold deserts, Genetic resources, Ladakh Himalayas

The loss of genetic diversity due to human activities has drawn the global attention for vegetational and floristic studies to develop biodiversity conservation programme in many countries including India. Mulberry (*Morus* species) is out breeding and highly heterozygous perennial tree. Its high biomass production and protein rich foliage nurture the sericulture industry in India besides it is extensively used in agroforestry and horticulture programmes. Mulberry is abundantly available under natural habitat in the Himalayan belt and under managed habitats of on-farm conservation throughout the country. The genus *Morus* comprises about 68 recognized species (Sanjappa, 1989). Presently there are about 1300 gene banks on agro biodiversity which are operating worldwide maintaining about 6 million germplasm accessions (FAO, 1998). Among the sericultural countries, China is holding largest mulberry germplasm collections (2600 accessions) followed by Japan (1375), India (1053), Korea (615) and Bulgaria (140) in the *ex situ* field gene banks. Vavilov (1926) placed genus *Morus* in China-Japan region for the centre of origin. The Centre of Diversity of mulberry exists in the entire Himalayan belt where the natural mulberry and their wild relatives exist in abundance upto elevation of 2200 m MSL extending between Indus and Brahmaputra rivers. Hooker (1885) reported four *Morus* species viz., *M. indica*, *M. alba*, *M. laevigata* and *M. serrata* occurring in India. Since then the distribution and variation of mulberry genetic resources in India including Andaman Islands have been systematically reported by several taxonomists and germplasm curators (Ravindran *et al.*, 1997 and 1999, Dandin *et al.*, 1995; Tikader *et al.*, 2001 and Chaurasia and Singh, 1996 and 2001). The Central Sericultural Germplasm Resources Centre, Hosur (Karnataka) is the National Active Germplasm Site (NAGS) for mulberry in India and is mandated to collect, characterize and conserve the mulberry genetic resources. This centre conducted more than 50 survey exploration trips across the country and collected

more than 660 mulberry genetic resources. Ladakh region of Jammu and Kashmir state remained unexplored till recently. Hence, an attempt was made to explore and survey cold deserts of Ladakh region for collection of frost tolerant mulberry genetic resources and identify locations for mapping of mulberry genetic resources, so that long-term conservation strategies could be evolved.

The Ladakh region is popularly known as High Altitude Cold Desert. It lies between 32° to 36° North Longitude and 76° to 79° East latitude sprawls over 96,701 sq. km with a low population. The Ladakh Himalayan range is rocky, barren and devoid of soil.

The survey area comprise Leh, Kargil, Suru Valley, Shyok-Nubra Valley and the altitude in these regions ranges from 3000 m and above to 5000 m AMSL. During the first phase, survey route covered 250 km from Leh to Kargil (Suru valley). The important places and adjoining villages covered were Spitok, Lamagaru, Nimmo, Sospol, Nurla, Khalatse, Lamayaru, Bodhkarbu, Namikala (3720m), Mulbeck, Lochum, Pashkyum and Kargil. In the second phase the survey route covered nearly 260km from Leh to Turtok (Nubra valley) and 142 km from Leh to Panamik. The villages covered were Gangles, Khardongla (5602 m), Khardong, Khalsar, Diskit, Hunder, Parthapur, Biagdong and Turtok.

A total of 14 mulberry germplasm resources (districts Leh-10 and Kargil-4) were collected in the Ladakh area and out of which 5 collections belong to *M. indica* and seven collections to *M. alba* and two collections remain unidentified (Table 1). The mulberry in Ladakh region is basically identified from the leaf morphological variation, style and stigma characters, fruit colour and other genetic characters (Koidzumi, 1917).

The detailed variability for morphological and reproductive characters of the mulberry collections from two districts of Ladakh is given in Tables 2 and 3. The distribution of mulberry in the Ladakh valley was sporadic

Table 1. Mulberry collections from different regions of Ladakh (J & K)

Districts	Area surveyed	Collection (Nos.)	Species (No. of accessions)
Leh	Nimmo, Ranabirpur, Spitok, Sospol, Nurla, Gangles, Khardongla, Khardong, Khalsar, Hundar, Diskit, Parthapur, Biagdong, Panamik and Turtok	10	<i>Morus indica</i> (3) <i>Morus alba</i> (6) <i>Morus species</i> (1)
Kargil	Kargil, Pashkyum, Lochum, Mulbek, Namikala, Bodhkarbu and Khalatse	4	<i>Morus indica</i> (2) <i>Morus alba</i> (1) <i>Morus species</i> (1)

in nature. Mulberry population is mostly available adjacent to the villages on the hill slopes along the rivers and under the managed habitats of *on-farm* conservation. The diversity of *Morus* species was confined to two species namely *M. indica* and *M. alba* mostly in the altitudes ranging from 2750-3310 m MSL. A long spell of sub-zero temperature in the Ladakh region forces mulberry trees in the dormant condition from October to February. The dormant buds get sprouted on the onset of spring during March-April along with the floral buds and during July the trees remain in full bloom with fruiting. The trees belonging to both the species were highly branched and short height comparative to the *M. laevigata* species. The adaptation to sub-zero temperature was predominantly seen by forming dormant buds in winter. Most of the trees had attained the age approximately between 50-150 years with the trunk circumference of maximum 12 feet. The trunk circumference and structure, leaf lobation, morphology, sex and reproductive characters varied greatly among the collections. The leaf apex was obtuse to acute in case of *M. indica* (Figure 1) and whereas *M. alba* collections have short acuminate leaf tips (Fig. 2). At Nurla the *M. alba* collections exhibited variation in leaf lobation with highly dissected leaves where the number of lobes ranged from 0-10 (Figure 2) and the internodal distance greatly varied among the population. Short internodal distance a desirable characters was recorded in the *M. alba* collection from Pashkum of district Kargil. However, the leaf phyllotaxy is 1/2 in all the collections. The female flowers had uniformly short styles with divericcate, pubescent and spreading stigma. A total of 14 mulberry germplasm resources representing *M. indica* and *M. alba* collected during the present survey trip exhibited wide variation in respect of morphological and reproduction characters. The trees were predominantly dioecious female and rarely monoecious in nature. The monoecious trees had all categories of inflorescence viz., pure male, pure female and bisexual in the same branches or different branches

of the same tree with different degree of cleistogamous condition. Irrespective of the species, the female flowers had short styles with divericcate and spreading stigma, which indicated the hybrid nature of the population between *indica* and *alba* types. According to the taxonomical classification of genus *Morus*, the *M. indica* L. group (syn. *Morus ausrtalis* P. and *Morus asidosa* G.) belongs to *Dolichostylae* (Long style >0.5 mm in length and connate at the base) and the fruit length is short and the colour is black with sour or less sweet in taste and *Morus alba* L. belong to *Macromorus* (short style < 0.5 mm in length and free at the base) and the fruit length is short and the colour is white, violet or pinkish with sweet (Koidzumi, 1917 and Rao *et al.*, 1999). However, the present collections, which belong to *M. indica* had short to moderate style length and sweet indicated the hybrid nature. The population studies of these variants will be useful for taxonomically revision of *Morus* spp. besides, conducting hybridization studies for exploitation of hybrid vigour for crop improvement. Intra and interspecific hybridization in *Morus* helps to incorporate desirable traits and to study inheritance pattern of genetic characters. Dominance of parental characters in the F₁ crosses of different intra and interspecific crosses of mulberry including *M. alba* and *M. indica* species have been reported by Dwivedi *et al.*, 1989 and Tikader and Rao, 2002.

The availability of the young seedlings on the sides of the water canals, bunds and riverbeds at Sanjak village in Kargil indicated high level of seed fertility due to monoecious condition of the trees where 90.8% seed germination was recorded (Fig. 3). However, seed development in some isolated female mulberry trees indicated possibility of apomictic lines and the studies on the embryological aspects of these lines will have great importance for development of new propagation methods in mulberry and crop improvement. In spite of high seed fertility recorded, the sparse distribution of natural mulberry trees observed in the valley needs a

Table 2. Variability of mulberry germplasm collections from district Leh of Ladakh range (J&K)

Characters	Places and collection details						
	Sospol	Sospol	Nurla	Hunder	Hunder	Biagdong	Turtuk
<i>Morus</i> species	<i>M. alba</i>	<i>M. indica</i>	<i>M. alba</i>	<i>M. alba</i>	<i>M. alba</i>	<i>M. indica</i>	<i>M. alba</i>
Altitude (m) MSL	3140	3140	3100-3140	3310	3310	3140	3310
Age in years	50	100*	10-60	100	120	100	200
Tree population	2 trees	1 trees	50 trees	15 trees	25 tree	25 tree	1
Purpose	Fruit and fodder	Fruit and fodder	Fruit and fodder	Fodder and fruit	Fruit and fodder	Fruit and fodder	Fodder and dry fruits
Trunk girth	5.6 feet	9.00 feet	1.6-5.0 feet	4.8 feet	4.8-6.0 feet	9-11 feet	12.0 feet
Shoot colour	Brown	Pinkish Brown	Brown	Brown	Brown	Brown	Brown
Leaf lobation	Unlobed	Unlobed	0-10 lobed	Unlobed	Unlobed	0-2 lobed	Unlobed
Phyllotaxy	1/2	1/2	1/2	1/2	1/2	1/2	1/2
Leaf shape	Ovate	Ovate	Ovate	Ovate	Ovate	Ovate	Ovate
Leaf apex	Acuminate	Obtuse	Acuminate	Acuminate	Obtuse-Acuminate	Obtuse	Acuminate
Leaf margin	Serrate	Serrate	Serrate	Serrate	Serrate-Dentate	Serrato-dentate	Serrate
Leaf base	Cordate	Cordate to truncate	Truncate-Cordate	Truncate	Truncate	Cordate	Truncate
Leaf surface	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
Leaf texture	Charatacious	Charatacious	Charatacious	Charatacious	Charatacious	Charatacious	Charatacious
Leaf size (L/B) cm	11.2 / 9.00	11.5 / 8.30	8.5-12.3/ 7.2-8.6	11.50/9.20	11.50-12.5/ 9.10-9.20	15.30/12.8	13.50/9.00
Petiole length	4.00	5.00	2.10-6.00	4.30	4.00-4.30	5.30	4.20
Internodal distance	5.8	6.5	4.30-9.1	6.10	4.00-6.10	4.50	4.50
Sex	Dioecious-Female	Dioecious-Female	Monoecious-Male and Female	Dioecious-Female	Dioecious-Male and dioecious Female	Dioecious-male	Dioecious-Female
Inflorescence length	2.5	2.0	2.5-2.8	3.20	2.50	2.50	2.0
Style length	Short	Short	Very Short	Short	Short	Short	Short
Stigma length	Short	Short	Short	Short	Short	Short	Short
Stigma type	Divaricate	Divaricate	Divaricate	Divaricate	Divaricate	Divaricate	Divaricate
Fruit length	3.10	2.10	2.60-2.80	3.20	2.50-3.20	3.20	2.60
Fruit colour	White	Black	White	White	Pinkish red	Black	White
Fruit taste	Sweet	Sweet	Sweet	Sweet	Sweet	Sweet	Sweet

case study for seed propagation under sub-zero temperatures at higher altitudes of Ladakh Himalayas. Probably the young seedlings generated during July-August months with fragile and weak root system do not survive the long spell of winter season with sub-zero temperatures particularly in sandy soils with high pH. Secondly, the meagre bird population in the high altitude region restricts spread of the germplasm resources in the valley.

The distribution of *Morus* species viz., *M. indica* and *M. alba* in the higher altitudes above 3000 m msl of the cold deserts of Ladakh Himalayas reported by the present survey and exploration opens new research lines to study the distribution and propagation of *Morus* species in the high altitudes with long spell of subzero temperatures. The absence of other *Morus* species viz., *M. laevigata* and *M. serrata* in the Ladakh Himalayas is rather interesting;

which are otherwise well distributed in the lower altitudes of adjoining northwest Himalayan ranges (Jammu & Kashmir, Uttaranchal and Himachal Pradesh) and requires more scientific investigation by conducting more survey trips to Indus, Changtang, Zaskar valleys of Ladakh to map the distribution of *Morus* species in high altitudes and diverse geographical areas. The studies on adaptation of *Morus* species to frost resistance will have great importance in developing frost resistant breeding lines in mulberry, which is required for development of sericulture in the temperate regions.

The total forest cover in the Ladakh valley is just 0.02% (45110 sq. km) and the broad leaved angiospermic flora is highly negligible which is the main cause for the oxygen depletion in the Ladakh region. Seeing the possibility of survival of *Morus* species in the higher

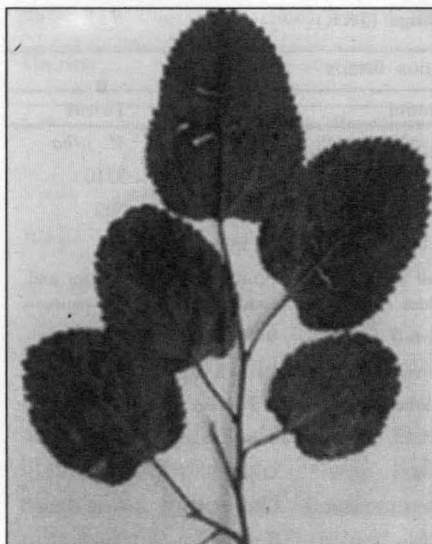
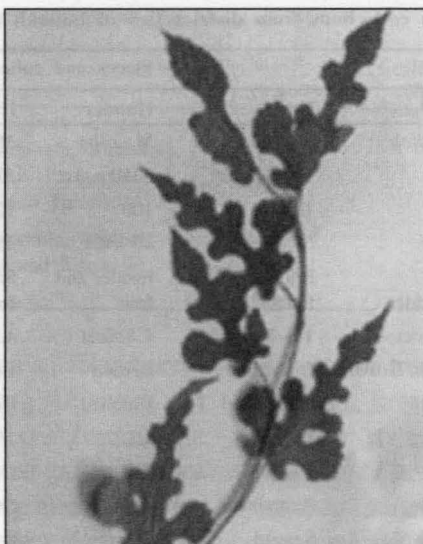
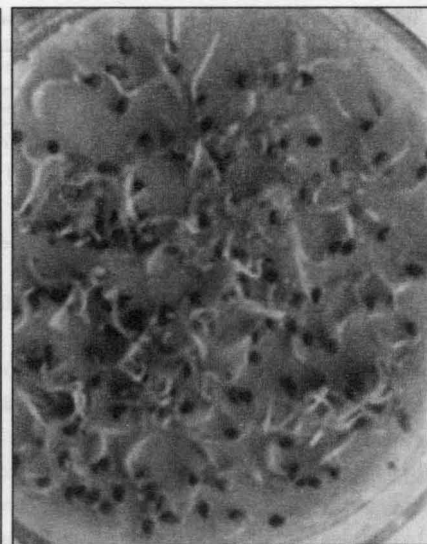
Fig. 1: Obtuse leaf apex of *M. alba*Fig. 2: Acuminate leaf apex and highly dissected leaf lobation of *M. indica*Fig. 3: Seed germination of *M. indica* at Sanjak

Table 3. Variability of mulberry germplasm collections from district Kargil of Ladakh range (J&K)

Characters	Places and collection details Pashkyum-Brokhur	Pasqum-Brokhur	Sanjak	Bheema
<i>M. Species</i>	<i>M. alba</i>	<i>M. indica</i>	<i>M. indica</i>	<i>M. indica</i>
Altitude	2950m	2950m	2840m	2750m
Age (approximately)	120	120	100	50
Tree population	3 trees	1 tree	About 100 trees	1 tree
Purpose	Fodder	Fruit and fodder	Fodder and fruit	Fruit and fodder
Trunk grith	5-5.4 feet	4.60feet	5 feet	2.7 feet
Colour of the shoot	Brown	Brown	Brown	Brown
Leaf lobation	0-5 lobed	Unlobed	Rarely 1 lobed	Unlobed entire
Phyllotaxy	1/2	1/2	1/2	1/2
Leaf shape	Ovate	Ovate	Ovate	Ovate to lanceolate
Leaf apex	Short acuminate	Acute	Acute	Acute
Leaf margin	Serrate	Serrato dentate	Dentate	Serrato
Leaf base	Truncate	Cordate	Cordate	Truncate
Leaf surface	Smooth	Smooth with dark green colour	Smooth	Smooth with dark green colour
Leaf texture	Charatacious	Charatacious	Charatacious	Charatacious
Leaf size (L/B)	7.8/ 3.0	12.0/9.10	19.50/15.80	12.0/9.10
Petiole length	2.30	4.50	6.20	4.50
Internodal dis.	3.80	5.00	6.10	5.00
Sex	Monoecious-(predominantly Female with few male flowers)	Dioecious-Female	Dioecious-Female	Dioecious-male
Inflorescence length	2.80	2.50	2.50	2.50
Style length	Very Short	Short	Short	Short
Stigma length	Short	Short	Short	Short
Stigma type	Divaricate	Divaricate	Divaricate	Divaricate
Fruit length	2.50	3.20	3.10	3.20
Fruit colour	Pinkish White	Black	Black	Black
Fruit taste	Sweet	Sweet	Sweet	Sweet

altitudes of Ladakh, introduction of diverse *Morus* germplasm resources in the valley will be certainly a positive step towards the development of greening in the valley. The high branching, protein rich foliage and high fruit yielding varieties of mulberry will not only improve oxygen levels in the atmosphere but also support fodder and fuel resources besides, fruit based industry which will improve socio-economic conditions of the tribal population of Ladakh.

Acknowledgements

The authors are grateful to Colonel B Rout, Director, Field Research Laboratory (FRL), Leh, J & K and Dr SK Dwivedi, Dr S Gomej and Dr Ankur Agarwal, scientists, FRL Leh for providing facilities and kind cooperation extended to the survey team in Leh and Kargil districts.

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SHORT COMMUNICATION

A Scented Sorghum Landrace from Bundelkhand Region of Uttar Pradesh**VS Singh, Mukesh Mohan¹ and Abhar Borkar¹***All India Coordinated Sorghum Improvement Project, Jhansi-284 204 (Uttar Pradesh)**¹ Department of Agricultural Biochemistry, CS Azad University of Agriculture and Technology, Kanpur-208 002 (Uttar Pradesh)***Key words: Scented sorghum, Protein, Tannin**

During a germplasm collection trip to Bundelkhand region of Uttar Pradesh in year 2002, a seed sorghum landrace possessing basmati-rice like aroma was identified. The germplasm of scented sorghum landrace, locally known as *Basmati* (MASC-1/2002 and MASC-2/2002) was collected from Sarila village of Hamirpur district (26°N, 80°E). The region is semi-arid, receiving 600-8000 mm rainfall annually, spread over 40-50 days during mid June to mid September. Soil types are mar, kabar, parawa and rokar of undulating topography and erodable nature. Although, the landrace is not very popular among farmers for general cultivation, some farmers cultivate it for their own consumption due to the characteristic flavour and taste for culinary preparation called 'kui' from immature seeds (dough stage).

Scented sorghum is planted in July and harvested in November in *kharif* season under rainfed conditions. The panicles are recurved (MASC-1/2002), erect (MASC-2/2002), deciduous awns and heads had characteristics of the race-durra. The ear heads and seeds emit mild scent like that of typical basmati rice. Green leaves of the plant also emit distinct aroma when tested using the KOH technique, devised to distinguish basmati rice plant from normal plants (Sood and Siddique, 1989).

The seeds of scented sorghum are dimpled, bold (35.5g/1000 seeds) and had soft endosperm (hardness 8.63kg/seed on OSK 201 grain hardness tester Type E). Chemical analysis of seeds showed high protein (11.44%) and low tannin (88.33m/100g). Nutritionally, seed protein

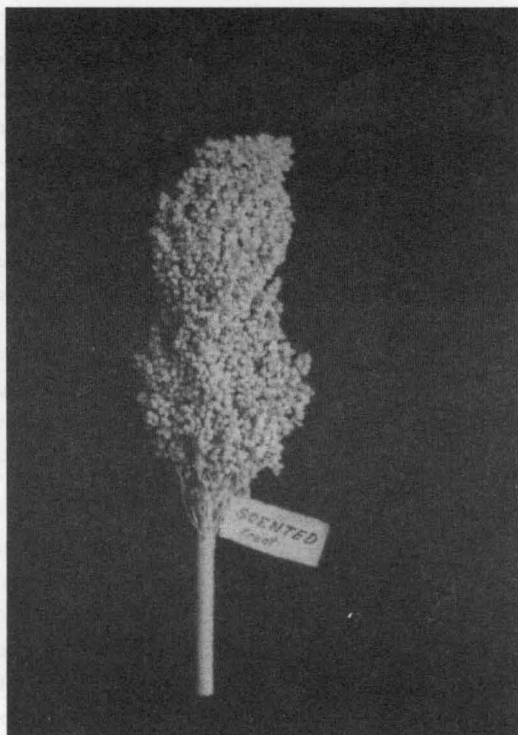


Fig. 1: Scented sorghum (erect)

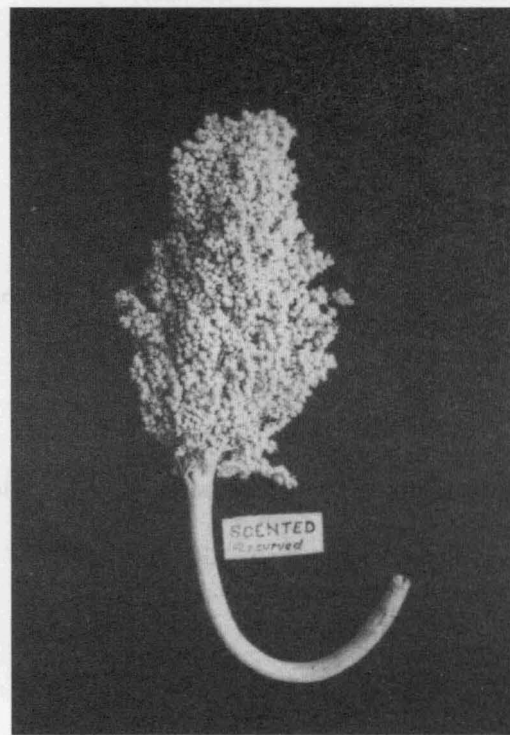


Fig. 2: Scented sorghum (curved)

could be rated of good quality as indicated by lysine content (1.6mg/16mgN), chemical score (22.72) and protein quality index for adults (73). The cultivar is under evaluation for yield potential during *kharif/rabi* seasons and for quantitative assessment of volatile aroma compounds. This local type may be utilized in the breeding programme for transfer of aroma character to other selected cultivars.

Acknowledgements

Authors are grateful to Dr Dhan Prakash, National Botanical Research Institute (NBRI), Lucknow, Uttar Pradesh for amino acid analysis of seed samples.

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SHORT COMMUNICATION

Arka Amulya – A New Variety of Guava from Punjab**JS Bal and GS Dhaliwal***Department of Horticulture, Punjab Agricultural University, Ludhiana-141 004 (Punjab)***Key words: Guava, Arka Amulya**

The guava is gaining popularity among fruit growers of Punjab because of its desirable quality and high productivity. It ranks second in area after citrus and occupies 6690 hectares with an annual production of 1.17 lakh mt (Anon, 2004). The districts of Sangrur, Patiala, Amritsar, Ludhiana and Ropar are known for guava cultivation. New plantations of guava are coming up fast in different parts of Punjab. Sardar (L-49) and Allahabad Safeda are the only two recommended varieties of guava. There was strong need to introduce another high-yielding and superior quality variety of guava to fetch higher premium in the market. Keeping this in view, Arka Amulya and Arka Mridula varieties of guava were tested for number of years to have another choice with the guava growers.

The trial on evaluation of guava varieties was carried out at Punjab Agricultural University, Ludhiana during 1997-2001. The plantation was made at 6 x 6 m distance. The plants of Arka Amulya and Arka Mridula were introduced from Indian Institute of Horticultural Research, Hessarghatta, Bangalore. The observations of fruit yield, fruit breadth, fruit weight, seed number per fruit, seed hardness, flowering time, fruit maturity and total soluble solids in fruits of both rainy and winter season crops were recorded. The seed hardness was recorded in terms of kg pressure. Total soluble solids (TSS) were determined with the help of Bausch and Lomb hand refractometer at 20°C with necessary correction factor. The results obtained are presented in Tables 1 and 2.

The cumulative fruit yield was recorded the highest in Arka Amulya (144.3 kg/tree) followed by Sardar (109.5 kg/tree). The winter season crop of guava is considered superior in quality. Arka Amulya resulted in higher yield during both rainy and winter season compared to the two recommended varieties. However, Bal (1997) reported variation in fruit yield in Sardar and Allahabad Sufeda than the yield recorded in Arka Amulya.

The fruit size in terms of breadth and weight was observed bigger in Arka Amulya. The average fruit breadth of rainy and winter season crop was 5.63 cm and 6.18

cm respectively. The fruit size was recorded little less in Arka Mridula, although the results were statistically non-significant among the three varieties tested. The average fruit weight in these three varieties varied from 95.6 g to 111.4 g in rainy season crop and 136.6 g to 159.3 g in winter season crop. The differences in fruit weight were also found at par in these varieties. However, Arka Amulya exhibited higher fruit weight compared to other two varieties.

The fruit quality was measured by recording total soluble solids. The total soluble solids were recorded slightly higher in the fruits of Arka Amulya in both rainy (9.30%) and winter season (10.13%) crops though the differences were found non-significant. The average range of TSS was recorded 8.36 per cent in Sardar in rainy season crop and 10.13 per cent in Arka Amulya in winter season crop. The results related to TSS in guava during rainy and winter season are in conformity with those reported in Sardar guava (Bal and Dhaliwal, 2003). The seed number per fruits were counted during both the cropping season and recorded lower in Arka Mridula (296/fruit) during rainy season crop and in Sardar (213/fruit) during winter season crop. Arka Amulya variety produced slightly more number of seeds. Seed hardness is the most important trait while selecting variety for general recommendation. Arka Amulya variety registered least hardness in seeds to the tune of 4.83 kg pressure. Seed hardness pressure was recorded almost double the value (9.68 kg pressure) in Sardar. It was also quite high in Arka Mridula (8.57 kg pressure).

The flowering in Arka Amulya occurred about 15 days advance during rainy season and 4 days advance during winter season as compared to variety Sardar. Ripening of fruits during rainy season took earlier in Sardar and peak ripening was observed between 2 to 22 August. The fruits of both Arka Amulya and Arka Mridula ripened between 10 to 30 August. However, ripening of fruits during winter season in all the three varieties started from December and continued up to end of January.

Table 1. Cumulative physico-chemical characteristics of fruit of guava varieties (1997-2001)

Guava varieties	Fruit yield (kg/tree)			Fruit breadth (cm)		Fruit weight (g)		TSS (%)		Number of seed (per fruit)		Seed hardness (kg pressure)
	R	W	Total	R	W	R	W	R	W	R	W	
Arka Amulya	46.5	97.8	144.3	5.63	6.18	111.4	159.3	9.30	10.13	381	305	4.83
Arka Mridula	37.0	57.2	94.2	5.37	5.90	95.6	136.6	8.77	9.52	296	293	8.57
Sardar	40.5	69.0	109.5	5.55	6.02	108.2	145.4	8.36	9.62	386	213	9.68
C.D.5%	NS	30.2	—	NS	NS	NS	NS	NS	NS	—	—	—

R: Rainy season; W: Winter season

Table 2. Flowering time and fruit maturity of guava varieties

Guava varieties	Flowering time		Fruit maturity	
	Rainy season	Winter season	Rainy season	Winter season
Arka Amulya	20 April-30 April	1 August-16 August	10 August-30 August	10 December-30 January
Arka Mridula	30 April-10 May	25 July-16 August	10 August-30 August	10 December-15 January
Sardar	5 May-15 May	5 August-20 August	2 August-22 August	10 December-30 January

Arka Amulya was recommended for general cultivation in the Punjab on account of high yielding and superior quality fruits. The fruit of this variety is large, round, glossy with white flesh. The average yield of rainy and winter season crop is 144 kg per tree. The total soluble solids in fruits ranged from 9.3 to 10.1. The cultivar can be propagated very easily on Sardar rootstock by patch budding in the month of May-June.

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SHORT COMMUNICATION

Identification of Male Sterile Strain in American Cotton with Red Pigmented Plant Body and Petal Spots

SL Ahuja, LS Dhayal and D Monga

Central Institute for Cotton Research, Regional Station, Sirsa-125 055 (Haryana)

Key words: American cotton, Male sterility, Red pigmentation

The cost of hybrid seed production in cotton can be scaled down considerably by eliminating manual emasculation using a male sterile line (Patil and Patil, 1973; Sheriff and Shivanandaiah, 1974; Srinivasan and Gururajan, 1974). Several workers have reported male sterility in American cotton (Justus and Leinweber, 1960; Richmond and Kohel, 1961; Weaver, 1968; Turcotte and Feaster, 1979). The main reasons for high cost for hybrid seed production in North Zone are: (i) short duration of flowering period (40-50 days) in comparison to central and south zones; (ii) boll setting period coincides with cloudy weather i.e., less number of sunny days during monsoon period and (iii) high wages of labour.

For successful development of hybrid an agronomic base of female line, preferably a male sterile line, as one of the parents of hybrid is desirable. For the purposes of maintaining the purity of a new variety in the seed production process, prominent morphological differences among varieties have to be found. Morphological features are indicative of the genetic make up of plant, and it is usually not difficult for breeders to identify their own varieties even with minor differences from other varieties. Seed production systems all over the world are still based on visual differences. Off types-deviations from the variety norm are eliminated, and it is assumed that the rest of the population is pure (ICAC 1996). Several workers have reported that morphological characters such as red plant body, frego bract, okra leaf, nectariless etc. are associated with resistance to cotton bollworms which is a major damaging insect pest in the country. Genotypes with these morphological traits have higher amount of gossypol, reducing sugar, flavonol and phenol contents (Lukefaher *et al.*, 1969; Brewer *et al.*, 1984; Ahuja *et al.*, 2001). Research efforts, therefore, are required to develop/ identify suitable male sterile lines with these morphological characteristics which could produce high yielding and superior fibre quality hybrids.

Seed of red plant body strain (popularly called as Lal Kapas by the farmers) was collected from farmer's field of village Nezaadela, 10 km. from Sirsa (Haryana) in the *kharif* 2003-04. The farmer informed that the red *kapas* plants were observed in a mixture of another variety purchased from a local seed seller. The seed of this strain was sown in *kharif* 2004-05 on May 24th. A total of 25 plants were raised. During a visit in the field in the month of September it was observed that there was no boll setting in one of the plants of Red Kapas strain. On examination of its flower it was found that there was no pollen in the bright noon. There was abundance of pollen in the other plants of this strain. To confirm sterility in this plant its flower was used as pollinator in the month of September, October and November on the variety RS-2013 and other fertile plants of this strain. There was no boll formation. Buds of this plant were selfed and it was found that there was no boll setting. On pollinating this plant with fertile flowers of other Red Kapas plants, there was setting of bolls. Boll setting was also obtained by pollinating RS2013 and CISOV-24 strains. These observations indicated that this strain can be used as sterile female for hybrid seed production. In the crop season maximum and minimum temperature during the flower development period varied in different months (August: 36.3 to 25.2°C, September: 36.8 to 21.9°C, October: 32.4 to 11.7 °C and in November: 31.3 to 8.8°C. In visual observations there was no pollen grain formation with the downfall of the maximum and minimum temperature also there was no boll setting on selfing. Therefore, it has been presumed that sterility identified was not a case of Gene-environment induced male sterility (TGM or PGMS). The above mentioned crosses attempted with this sterile plant will be sown separately to confirm further the type of sterility.

For majority of the traits this plant had similar characteristics (Table 1) like other Red Kapas plants *viz.* presence of petal spots, small flowers with red /pinkish

Table 1. Characteristics of red pigmented sterile and normal red pigmented plant

Character	Red pigmented sterile plant	Red pigmented normal plant
Plant type	Lanky	Lanky
Plant height(cm)	110	65-95
Leaf colour	Red	Red
Leaf size	Small	Small
Stem colour	Reddish	Reddish
Petal spot	Red petal spot present on each of the petal	Red petal spot present on each of the petal
Degree of redness of petal spot	Increases with the age of the flower	Increases with the age of the flower
Petal colour	Yellow with red margin	Yellow with red margin
Pollen colour	Pollen grains absent	Light yellow
Monopods/plant	1-9	3
Sympods/plant	3-11	6
Days to maturity	170-175 days	150-160 days
Bolls/plant	—	25-45
Seed cotton yield/plant	—	75 g to 135 g
GOT (%)	35*	35
Seed	Fuzzy*	Fuzzy
Lint colour	White*	White
100 seed weight (g)		
Boll weight (g)	3.40*	3.23
Boll shape	Oval pointed tip*	Round with tip
Locules /boll	4*	4
Seeds/boll	24-28*	25-28
Seeds/locule	6-8*	6-8
Disease reaction	Tolerant to CLCuV	Tolerant to CLCuV
Insect pests incidence	Tolerant	Tolerant

* Observations recorded in cross bolls

margins, etc. but differed in boll shape and blooming duration.

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SHORT COMMUNICATION

Association Analysis for Quality and Yield Components in Some Indigenous Scented Rice Accessions

Deepak Naik, Abhinav Sao and AK Sarawgi

Department of Plant Breeding and Genetics, Indira Gandhi Agricultural University, Raipur-492 006 (Chhattisgarh)

Key words: Scented rice, Correlation

The estimates of correlation and association of characters are very useful in understanding the nature and magnitude of genetic variability available in the breeding programme. Grain yield in rice is a complex trait which is influenced by a number of component characters and environment directly or indirectly for the development of high yielding genotypes. Most of the scented indigenous genotypes are low yielding. Therefore, for the development of high yielding scented variety, knowledge of interrelationship among yield and its attributing traits is quite necessary. A correlation study in conjunction with path coefficient analysis provide the information about cause and effect relationship between direct pairs of variables.

The present study was conducted at research farm, Department of Plant Breeding and Genetics, Indira Gandhi Agricultural University, Raipur during *kharif* 2001. The experimental material (Table 1) for this study comprised of fifty selected traditional rice accessions along with improved aromatic varieties as checks *viz.* Pusa Basmati-1, Tarori Basmati, Indira-9, Dubraj and Madhuri-11. The experiment was conducted in randomized block design with two replications. Each genotype was grown in a 3 m long row length. The row to row and plant to plant spacing was 20 and 15 cm respectively. Five plants from each row were randomly selected and observations for characters *viz.*, plant height, panicle length, effective tillers per plant, biological yield per plant, paddy length, paddy breadth, paddy length: breadth ratio, kernel length, kernel breadth, kernel length: breadth ratio and grain yield per plant were recorded. Data were subjected to correlation coefficient analysis as per formulae given by Miller *et al.* (1958) and path coefficient analysis by Dewey and Lu (1959).

In the present correlation coefficient (Table 1) study grain yield per plant expressed a positive significant association with biological yield per plant at phenotypic, genotypic and environmental level. It expressed negative

significant association with panicle length, paddy breadth and kernel breadth at genotypic level. Biological yield per plant had a significant positive association with grain yield per plant at phenotypic, genotypic and environmental level while, with paddy breadth it showed significantly negative association at genotypic level.

The positive and significant correlation of plant height was found with panicle length and biological yield per plant at phenotypic and genotypic level while, it had significant negative association with paddy length, paddy length: breadth ratio, kernel length and kernel length: breadth ratio of phenotypic and genotypic level. The number of effective tillers per plant showed a significant positive correlation at genotypic and environmental level with grain yield per plant while, it showed significant negative correlation with paddy breadth at genotypic and phenotypic levels and with kernel breadth at genotypic level. Panicle length recorded significant negative association with paddy length, paddy length: breadth ratio, kernel length and kernel length: breadth ratio at phenotypic and genotypic level.

In this study, grain yield per plant had positive association with biological yield per plant and effective tiller per plant as reported by Annadurai (2001). Effective tillers per plant had a positive association with grain yield. Similar result was reported by Basavaraja *et al.* (1997). Positive significant association of biological yield per plant with grain yield per plant in the present study was in agreement with the findings of Rao and Shrivastava (1994).

Path coefficient analysis of different characters contributing towards grain yield per plant revealed that paddy length had the highest positive direct relationship with grain yield per plant followed by paddy breadth, biological yield per plant and effective tillers per plant. Positive direct effect of various characters on grain yield observed in the present findings are in agreement with

Table 1. Genotypic (G), phenotypic (P) and environmental (E) correlation for morphological and quality traits

Characters		Effective tillers/ plant	Panicle length (mm)	Biological yield/plant	Paddy length (mm)	Paddy breadth (mm)	Paddy L:B ratio	Kernel length (mm)	Kernel breadth (mm)	Kernel L:B ratio	Grain yield/ plant
Plant height	P	0.030	0.622**	0.342*	-0.533**	0.081	-0.467**	-0.521**	0.152	-0.427**	-0.041
	G	0.046	0.658**	0.433**	-0.550**	0.088	-0.492**	-0.546**	0.143	-0.445**	-0.144
	E	-0.160	-0.032	0.146	-0.041	-0.044	-0.056	-0.005	0.268	-0.181	0.093
Effective tiller/plant	P		-0.029	0.215	-0.060	-0.298*	0.065	-0.058	-0.267	0.101	0.257
	G		-0.021	0.235	-0.065	-0.318*	0.066	-0.067	-0.296*	0.114	0.409**
	E		-0.132	0.217	0.024	-0.087	0.054	0.066	-0.013	-0.016	0.306*
Panicle length	P			-0.071	-0.418**	0.080	-0.321*	-0.416**	0.134	-0.358*	-0.251
	G			-0.085	-0.435**	0.080	-0.342*	0.441**	0.126	-0.379**	-0.491**
	E			-0.055	0.056	0.074	0.020	0.097	0.256	-0.070	-0.221
Biological yield/ plant	P				-0.051	-0.232	0.040	-0.026	-0.192	0.052	0.563**
	G				-0.063	-0.305*	0.010	-0.076	-0.267	0.054	0.652**
	E				-0.038	-0.045	0.203	0.237	0.009	0.069	0.597**
Paddy length	P					-0.063	0.838**	0.961**	-0.154	0.806**	0.065
	G					-0.071	0.873**	0.992**	-0.169	0.854**	0.150
	E					0.195	-0.034	-0.110	0.151	-0.167	0.010
Paddy breadth	P						-0.513**	-0.071	0.955**	-0.497**	-0.185
	G						-0.503**	-0.081	0.990**	-0.527**	-0.417**
	E						-0.657**	0.118	0.549**	-0.092	-0.054
Paddy L:B ratio	P							0.831**	-0.601**	0.938**	0.113
	G							0.874**	-0.600**	0.990	0.164
	E							0.029	-0.631**	0.275	0.200
Kernel length	P								-0.176	0.842**	-0.080
	G								-0.190	0.866**	0.129
	E								0.019	0.509**	0.144
Kernel breadth	P									-0.607**	-0.172
	G									-0.633**	-0.348*
	E									-0.335*	-0.107
Kernel L:B ratio	P										0.115
	G										0.220
	E										0.094

** Significant at 1% level ; * Significant at 5 % level

the findings of Surek *et al.* (1998) for biological yield per plant and Gupta *et al.* (1999) for panicles per plant.

To conclude, that the selection criteria based on effective tillers per plant, grain yield per plant and biological yield per plant can provide better result for improvement of yield. The study of path analysis indicated that the direct selection of biological yield per plant and effective tillers per plant would be used as selection criteria for improvement.

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SHORT COMMUNICATION

Performance of Early Ripening Varieties of Ber

JS Bal and JS Randhawa

Department of Horticulture, Punjab Agricultural University, Ludhiana-141 004 (Punjab)

Key words: Ber, Early ripening, Performance, Varieties

During the past few years, ber growing has become very popular in Punjab, Haryana, Uttar Pradesh and dry lands of Rajasthan due to its wider adaptability and higher economic return. A comprehensive collection of ber cultivars from various sources have been made at Punjab Agricultural University, Ludhiana. These varieties were raised by budding *in situ* on *katha* ber seedlings. Out of four recommended varieties in Punjab, two are mid season and two are late ripening varieties. No early ripening variety is available for cultivation in the state. Therefore, strong need was felt to introduce early ripening variety for economic marketing.

The investigation on the performance of early ripening ber varieties was carried out at Punjab Agricultural University for five years from 1991-92 to 1995-96. This trial included ten early varieties for evaluation viz., Gorva, Narikeli, Nazuk, Rohtaki Gola, Safeda, Sandhura Narnaul, Selected Safeda, Seo, Surti and Wallaiti. These early varieties were compared with existing four recommended varieties (Kaithli, Sanaur-2, ZG-2 and Umran) as a check. The observations on ripening time, fruit size, fruit weight, fruit yield, palatability rating, powdery mildew incidence, total soluble solids value and acidity were recorded. Palatability rating was tested by a panel of five judges on the basis of general appearance and taste and flavour (10 marks). The ber varieties were rated as excellent (9-10 marks), very good (8-9 marks) and good (7-8 marks). Total soluble solids were determined with the help of Bausch and Lomb hand refractometer at 20°C with necessary correction factor. The acidity was estimated in terms of citric acid titrating with N/10 NaOH solution.

The ripening time of different early varieties spreads over a period of one month from second fortnight of February up to first fortnight of March. Among these varieties Nazuk, Rohtaki Gola, Safeda and Selected Safeda ripened earliest i.e. during the second fortnight of February. However, most of the early varieties ripened during first fortnight of March. This is a time when season for most of the fruits is practically over. The

ber fruit of early varieties sell readily at remunerative prices. The ripening time of mid-season varieties (Kaithli and Sanaur-2) is from mid-March to first week of April, whereas, the late varieties like ZG-2 and Umran ripen from end of March to mid-April.

The fruit size in terms of length and breadth varies greatly among the early varieties. The maximum fruit size was recorded in Wallaiti (4.3 x 2.7 cm) followed by Sandhura Narnaul (4.3 x 2.5 cm) and Narikeli (4.1 x 2.8 cm). The average fruit weight in different early varieties varied from 8.0 - 17.3g. The fruit weight was highest in Wallaiti (17.3 g) and Narikeli (16.0 g). However, the commercial variety Umran produced the heaviest fruits weighing 27.2g. Chadha *et al.* (1972), Bal and Jawanda (1981) and Bal and Uppal (1992) have reported large sized and heavier fruit of Umran. Different early varieties yielded 6.1 to 116 kg fruit per tree. The average yield was recorded the highest in Narikeli (116 kg) and Wallaiti (114 kg). Gupta (1977) reported little variation in fruit yield in Nazuk and Narikeli varieties due to different agroclimatic conditions prevailed and cultural practices adopted in Patiala areas. However, Bal (2001) while working on ber varieties reported similar observations with regard to fruit yield per tree basis.

Most of the ber varieties on full maturity possess golden yellow, light golden yellow, light yellow and greenish yellow colour. Of these, golden yellow colour seems to be the most appealing to the consumer. Wallaiti had very attractive golden yellow colour at maturity. Narikeli, Nazuk, Sandhura Narnaul and Surti develop light golden yellow colour at maturity. Almost similar fruit colour in ber varieties were earlier reported by many workers (Gupta, 1977; Bal and Jawanda, 1981; Aulakh, 1994 and Bal, 2002). The highest palatability rating (8.9) was recorded in Wallaiti among the early varieties and rated 'Very Good'. The commercial variety Umran with palatability rating 8.2 also rated as 'Very Good'. Sanaur-2 is the only variety having highest rating (9.6) and therefore rated as 'Excellent'.

Table 1. Cumulative physico-chemical characteristics of fruit of ber varieties

Name of the variety	Ripening time	Size		Weight (g)	Yield (kg/tree)	Colour	Palatability rating (10)	TSS (%)	Acidity (%)	Powdery mildew incidence
		Length (cm)	Breadth (cm)							
Rohtaki Gola	2nd fortnight February	3.6	2.5	13.2	62	Greenish yellow	7.8	13.1	0.35	11.0
Safeda	2nd fortnight February	2.6	2.2	8.0	83	Light yellow	7.8	14.8	0.41	13.0
Selected Safeda	2nd fortnight February	3.5	2.9	12.0	100	Light yellow	7.6	14.8	0.33	13.4
Nazuk	Mid Feb-Early March	3.5	2.1	8.2	82	Light golden yellow	8.4	16.2	0.25	10.0
Sandhura Narnaul	Mid Feb-End March	4.3	2.5	14.6	90	Light golden yellow	7.9	14.4	0.28	14.0
Wallaiti	1st fortnight March	4.3	2.7	17.3	114	Golden yellow	8.9	14.4	0.28	8.0
Gorva	1st fortnight March	3.3	2.7	13.3	90	Yellow green	7.5	14.2	0.38	
Narikeli	1st fortnight March	4.1	2.8	16.0	116	Light golden yellow	7.5	13.1	0.29	14.5
Seo	1st fortnight March	3.4	2.9	15.8	75	Light yellow	8.2	14.0	0.27	11.0
Surti	1st fortnight March	3.6	3.2	15.6	61	Light golden yellow	7.7	13.8	0.48	6.0
Sanaur-2	15 March-1st week April	4.4	3.1	22.8	138	Light yellow	9.6	18.4	0.43	2.8
Kaithli	End of March-1st week April	4.6	2.9	19.4	113	Light yellow	8.8	15.8	0.28	11.0
ZG-2	20 March-Mid April	3.1	2.6	14.2	43	Greenish yellow	8.1	13.4	0.27	3.0
Umrn	End of March - Mid April	4.5	3.3	27.2	148	Deep golden yellow	8.2	14.8	0.21	8.0
C.D. at 5%		0.16	0.13	1.3	11.1		0.47	0.78	0.07	3.2

The total soluble solids (TSS) in early varieties ranged from 13.1 per cent to 16.2 per cent ranging the highest in Nazuk (16.2%) followed by Safeda and Selected Safeda (14.8%) and Wallaiti and Sandhura Narnaul (14.4%). The minimum TSS value (13.1%) was noted in Narikeli and Rohtaki Gola. Acidity was estimated lowest (0.25-0.28%) in Nazuk, Seo, Wallaiti and Sandhura Narnaul and highest (0.48%) in Surti. However, Gupta (1977) reported higher acidity in Nazuk variety as compared to those discussed in the present studies.

All the early ber varieties were susceptible to powdery mildew disease to varying degree. The least incidence of disease was observed in Surti (6%) and Wallaiti (8%). The varieties like Narikeli and Sandhura Narnaul are more prone to powdery mildew and disease incidence was recorded 14.0-14.5 per cent. This disease can be effectively controlled with timely sprays of Karathane.

On the basis of above finding, Wallaiti was recommended as early variety for general cultivation in the state. Wallaiti is having attractive fruits with excellent rating qualities and stands better acceptability. The fruits are available when other four recommended varieties are not ripened yet. Thus, growers can get good returns by planting this variety.

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SHORT COMMUNICATION

Sources of Resistance to Barley Stripe Rust from Uttaranchal**KC Muneem***National Bureau of Plant Genetic Resources, Regional Station, Bhowali-263 132, Nainital (Uttaranchal)***Key words:** Barley, *Hordeum vulgare*, Resistance, Stripe rust

In the Northern hills of India, Barley (*Hordeum vulgare* L.) is an important cereal as regards total area and production. The Northern hills of India extend from Jammu and Kashmir, Himanchal Pradesh to the Northern hilly region of Uttaranchal. The area occupied by barley in Northern hills is about 0.12 m ha. It is grown under rain fed as well as in irrigated condition. Its production is effected by several fungal diseases. Stripe rust caused by *Puccinia striiformis* Westend is an important disease responsible for losses. The disease can be controlled by using different fungicides (Brahma and Asir 1988; Singh 1984b). Keeping in view, the seriousness of the disease and limited use of fungicides due to poor economic condition of farmers, an attempt was made for screening of barley lines under natural condition to identify resistant once against stripe rust disease. Earlier, Khanna *et al.* 1968 and Singh 1984 have reported some varieties resistant against *P. striiformis*.

The present study was conducted at NBPGR Regional Station Bhowali, which is situated at an altitude of 1660 m. asl, and known as a hot spot for disease development. Generally yellow rust and powdery mildew of wheat and barley appear in an epidemic form.

A set of 500 collections of barley was grown in field during crop seasons 1998-99 and 1999-2000 and 179 collections during 2003-04 and 2004-05 under irrigated condition in 2 m rows. Mixture of highly susceptible barley cultivars viz., DL 269, P 662 and RS 6 was used as infector rows around nursery.

The artificial epiphytotic was created to ensure the maximum development of the diseases using phytotypes G 19 and 57.

The rust intensity was recorded using modified Cobb's scale. Final observations were noted at the time of maturity. Out of a total 679 accessions under investigation only eight accessions viz. NC58178, NC60599, NC60607, NC60602, NC26553, EC492354, EC492370 and EC492346 were completely free from yellow rust. Other entries were highly susceptible to this rust. Therefore, these accessions could be utilized in the breeding programmes as a donor for resistance to stripe rust.

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BOOK REVIEW

N Tomooka, DA Vaughan, H Moss and N Maxted 2002. The Asian Vigna: Genus Vigna Subgenus Ceratotropis Genetic Resources. Kluwer Academic Publishers,

Dordrecht/Boston/London. ISBN No. 1-4020-0836-8.

Vigna is a large pan-tropical genus with nearly 90 species distributed among seven subgenera and 19 sections. Subgenus *Ceratotropis* of genus *Vigna*, the focus of the present publication, occurs predominantly in the Asia-Pacific region encompassing three adjacent mega-centres of diversity, namely Chinese-Japanese centre, Hindustani centre and Indo-Chinese-Indonesian centre. This subgenus, characterized by distinctive floral structure, includes several cultigens that are major or minor legume crops of Asia.

Genus *Vigna* subgenus *Ceratotropis* has been the focus of taxonomic study and collection in genetic resources programmes. Systematic studies on the *Phaseolus-Vigna* group of genera by R Marechal, JM Mascherpa and F Stainier (1978) has provided the impetus for study of individual subgenera within their centres of diversity. Studies have focused on one or a few related cultigens and their wild gene pools, usually within a mega-centre of diversity, and taking into consideration evidences of relationships through crossability studies, biochemical and molecular approaches and from an ecological perspective. The present publication addresses the problem of "the lack of a comprehensive body of work on the Asian legumes and their wild relatives", by bringing together much of the published information with emphasis on the Chinese-Japanese centre and parts of Indo-Chinese-Indonesian centre. This publication is conceptualized as a monographic work with chapters on taxonomy and biosystematics, genetic resources, species conspectus and eco-geographic analysis. Evaluation of research findings on cross-compatibility, nutritional aspects, disease resistance and biotechnology has been used for working out future perspectives for research from a genetic resources point of view.

The chapter on species conspectus of the Asian *Vigna* group provides morphological description based on a comprehensive set of characters including seedling characters. Descriptions of the species are based primarily on individual specimens but specimens collected and studied are listed and presented as distribution maps. Taxonomic affinities and diagnostic characters are

highlighted along with illustrations. Furthermore, attractive colour photographs of seeds and flowers of the different species and habitat photographs of selected ones are included in this publication, which in part are an update of the web-based illustrated legume genetic resources (1997). Species of the subgenus *Ceratotropis*, in this chapter, have been grouped into three sections on the basis of morphological traits and eco-geographic characteristics, namely *Aconitifoliae*, *Angulares* and *Ceratotropis*. Several new species have been created and described in the section *Angulares* related to the *V. angularis* – *V. umbellata* group of cultigens (adzuki bean and rice bean, respectively), which has maximum diversity in the Chinese-Japanese and Indochinese-Indonesian centres. This reflects the viewpoint of the authors based on research findings in these regions. This is an asset, particularly for workers in the South Asian region, as the conspectus provides a much-needed base for comparison and comprehensive assessment of species diversity in adjacent regions. Additionally, it is useful for genetic resources programmes, as a stimulus for collection and conservation efforts "that combine specialists of different plant groups to map, analyse and monitor crop relatives in several major protected areas".

Domesticated Asian *Vigna* species are "secondary crops" in comparison to soybean and have been referred to as "slow runners" vis-à-vis improvements in major crops. Asian *Vigna*, in this publication, has been considered from the genetic resources point of view in terms of conservation, both *ex-situ* and *in-situ*. Within the Asia-Pacific region, several national and international organisations are involved in maintenance of germplasm of cultigen and wild species. Figures given for conserved species highlights a major problem in documenting conserved germplasm of wild relatives of crop plants, namely lack of authentic figures in most collections of the region.

In-situ conservation particularly with regard to availability in protected areas and sympatric occurrence of species have been used to pinpoint areas for genetic analysis studies. Methodology, in general, has been given

major emphasis for collection, evaluation and characterization, and study of diversity from the genetic resources point of view. For eco-geographic analysis, pinpointing target areas for *in-situ* conservation, where species richness corresponds to areas of species diversity, detection of complex populations with "wild-like" plants with more diversity than the wild species and factors critical in maintaining populations *in-situ*, namely disturbance and pollinators are significant aspects for future consideration and study.

The consolidated analysis of information indicates that subgenus *Ceratotropis* of genus *Vigna* is a rapidly evolving group, so that the "original" habitat of each species may never be known; what is being studied and collected are ecotypes adapted to man-made environments.

This raises the concern about methods that are appropriate for conservation of weedy populations. Cultigens of Asian *Vigna* group will "always be secondary crops on a global scale" but this book provides an impetus to other stakeholders within the region of diversity to work out the ecogeographic patterns in this group. Several trends noted for the Asian *Vigna* group have also been noted in other crop groups of these regions particularly rice where intensive work has been undertaken. The present publication, therefore, provides useful source material not only for legume workers but also for others working with native crops of the Asian region.

– E Roshini Nayar, National Bureau of Plant Genetic Resources, New Delhi-110 012.

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