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Review

Breeding in Mango

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ABSTRACT

The Mango (*Mangifera indica* L.), member of family Anacardiaceae, is amongst the most important tropical fruits of the world. The opportunity for breeding improvement in the mango is significant and challenging. There is a lot more varietal wealth available but certain inherent constraints are involved like: long juvenility, high clonal heterozygocity, one seed per fruit, recalcitrant seeds, polyembryony, early post-zygotic auto-incompatibility and large area requirement for assessment of hybrids. On the other hand, wide range of diversity and ease of vegetative hybrid propagation are the advantages for the breeders. There are very few man made commercially important hybrids. Its development is mostly based on the selection of clones/chance seedlings made for fruit quality only. Requirements of a good cultivar involve: dwarfness, precocity, profuse and regular bearing, attractive, good sized and quality fruit, absence of physiological disorders, disease and pest resistance and improved shelf life etc. Comprehensive knowledge about the phenology, inheritance patterns of mango and advanced techniques for hybridization have been quite helpful to overcome the problems like irregular bearing, susceptibility to diseases and pests, poor eating and keeping quality. The development of the genetic markers has further reduced the uncertainty in breeding mango and maintaining the hybrid populations in a better way.

Key Words: Breeding; Mango

INTRODUCTION

The Mango (*Mangifera indica* L.), one of the 73 genera of the family Anacardiaceae in order Sapindales, is amongst the most important tropical fruits of the world. It is also called as king of the fruits (Purseglove, 1972). It originated in the South East Asian or Indo-Burma Region having 41 recognised species of mango originating as forest trees with fibrous and resinous fruits ((Mukherjee, 1951, 1967).

Mango has been cultivated for thousands of years in India (Mukherjee, 1953; Kostermans & Bompard, 1993) and its cultivation is as old as Indian civilisation (DeCandolle, 1884). Its development and culture in the sub-continent is mainly contributed by the Mughal Emperors especially Akbar who planted Lakh Bagh, amateur gardeners, nurserymen and farmers by means of selection and subsequent cloning. Now, it is an integral part of history and culture of Indo-Pak subcontinent.

Though soil and climatic conditions are highly suitable for mango production, Pakistan is still far behind in yield per hectare than the major mango producing countries of the world. At present, world is producing 23455 metric tons (MT) of mangoes. India is the largest producer (12000 MT) of mango followed by China (2142 MT), Mexico and Thailand with about 50 commercial producers of mango worldwide. Among mango exporters, Mexico is the largest one (209.4 thousand tons) followed by India and Philippine. Pakistan is standing at 5th place by contributing only 3.9% (916.4 MT) in the total world production. Total mango export from Pakistan is 40.2 thousand tons only and earning about six million US $ annually. Main importers from Pakistan involve Dubai, U.K. and Saudi Arabia. Exports can be lifted up rapidly by facilitating the growers and providing them incentives for production and subsequent export. (Anonymous, 1998-99; FAO, 1999)

The improvement of mango rather any crop needs to explore new recombinants primarily by means of exploiting the breeding methodologies. Diversity or heterogeneity is the main character desired for breeding either natural or manmade. It is required to have vast genetic pool to get new combinations of desired nature and developing new hybrids. It has been mentioned earlier that the development of mango in the area (Indo-Pak subcontinent) is result of selections from the amteur gardeners. Breeding has yet to play its role in the development of this crop as it has not been effectively manipulated in the distant past. Now, the scientists have developed certain hybrids of mango. To go for such strategies, a comprehensive knowledge of the physiology of the reproductive parts, their breeding behavior and cytological information of the crop is needed. This will eventually help Pakistan improve mango production status.

REPRODCUTIVE PHYSIOLOGY

Floral biology. Mango inflorescence is terminal with frequent emergence of the multiple axillary panicles. Both perfect (2-70%) and hermaphrodite flowers occur on the same panicle (Fraser, 1927). Total number of panicles is 1000-6000 depending upon the variety (Mukherjee, 1953). Anthesis starts early in the morning and completes at noon. Stigma receptivity remains for 72 h but most receptive period is for the first 6 h. Minimum pollen germination time is 1.5 h (Spencer & Kennard, 1955). Initial fruit set depends upon the ratio of the perfect to male flowers (Iyer *et al*., 1989). Proportion of perfect flowers required for optimum fruit set must not be less than 1%.

Pollination. Mango is self-fertile (Sturrock, 1944) but cross pollination increases fruit set (Popenoe, 1917). Some self-unfruitful cultivars may get benefit from cross-pollination. There is almost no air-borne pollen since it is heavy and adherent. The eye irritation (dermatitis) may result from volatile oils from flowers, mangiferol (sesquiterpene alcohol) and mangiferone (ketone). Young (1942) studied pollination of 'Haden' mango in Florida and found no significant difference between percentages of set in selfed and cross-pollinated flowers. Naturally more than 50% flowers don't receive any pollen.

Self-pollination may also occur in some cultivars (Dijkman & Soule, 1951). Though the ratio of hermaphrodite to male flowers is cultivar related, cool temperatures may also influence sex expression to favor majority of male flowers. There are several hundred flowers in a panicle and less than 1% only develop fruits because of pollination failure and premature fruit drop. Singh *et al*. (1962) reported that crossed flowers set fruit; whereas, selfed ones did not, indicating self-sterility. The actual degree of self-fertility and sterility in individual cultivars has not been determined, but there is some variation. Though self-sterility is not a major problem in fruit set, but within cultivar, there is a definite need for a pollinating agent. Popenoe (1917) stated that some of the embryos are capable of development without fertilization, however, Naik and Rao (1943) obtained no parthenocarpic fruit set of more than 100,000 flowers studied. The effect of cool weather adversely affects pollen tube growth, but this was not considered to be of major importance (Young, 1955). Wolfe (1962) concluded that getting flowers to set fruit was more of a problem than getting trees to bloom. The studies indicate that the need for cross-pollination between mango cultivars is not critical, at least for most cultivars, but pollinating insects are needed to pollinate within cultivar to get satisfactory crop.

Pollinizers. Several agents have been credited as pollinators of mango. Wagle (1929) showed that there was some selfing and wind pollination, but insects (bees, ants, and flies) played an important part. Popenoe (1920) disagreed with him and stated that there is no wind pollination observed in mango rather it is strictly an insect-pollinated plant. Mostly insects and to some extent wind and gravity do (housefly, honeybees and thrips) cross-pollination (Malik, 1951). Galang and Lazo (1937), and Singh and Sturrock (1969) supported him. Studies showed that plants caged to exclude all insects set no fruit but a plant caged with honeybees set a heavy crop (Sharma, 1987).

Popenoe (1917) reported that honeybees were the most important hymenopterous insect visitors to the mango flowers, with variability in number. Young (1942) recommended placing colonies of honeybees in mango groves. Simao and Maranhao (1959) reported low population of honeybees in mango. Singh (1954) listed mango as a nectar source for bees. While, Singh (1960) stated that honeybees do not visit mango flowers. Singh (1961) reported that over 65% of the perfect flowers were never pollinated showing that wind is not an effective pollinating agent. Complaints about lack of adequate fruit set in large plantings particularly of monoclonal cultivars are frequent (Singh & Sturrock, 1969). The mango flowers do not appear to be attractive to honey bees as they tend to open when many other flowers are also available leading to poor visitation in commercial groves. Pollination occurs by mainly wild insects while the use of the honeybees are unnecessary.

Cytology. On the basis of studies on certain *Mangifera* species (*M. indica, M. caloneura, M. sylvetica, M. foetida, M. caesia, M. odorata and M. zeylanica*), the basic chromosome number of mango have been found to be 2n=40 and n=20 (Roy & Visweswariya, 1951; Mukherjee, 1957). Mukherjee (1950) reported mango as an allopolyploid. Easy and frequent interspecific crossing is observed in mango (Mukherjee, 1953).

Polyembryony. Incidence of polyembryony is genetically controlled character. Leory (1947) found adventive embryony reflecting the effect of one or more recessive genes. Sturrock (1968) supported Leory (1947) as he found monoembryony as a dominant character in mango hybridization.

Incompatibility. Dijkman and Soule (1951) suspected self-sterility in mango but the prevalence was established in cv. Dashehari by Singh *et al*. (1962). The cultivars of mango like Dashehari, Langra and Chausa were found to be self-incompatible (Sharma & Singh, 1970). Ram *et al*. (1976) reported incidence of cross incompatibility among certain mango cultivars and suggested use of certain pollinizers.

Character inheritance. High heterozygosity and the inadequate number of hybrid progenies have made it difficult to analyze the genetics of mango. Dwarfness, regular bearing and precocity are characters controlled by the recessive genes while regularity of bearing is linked with precocity (Sharma & Majumder, 1988a). Lavi *et al*. (1989) observed that there is no maternal effect on juvenility and fertility while there is slight effect of female parent on fruit taste, size, color and harvest season. The flesh color inheritance is a multigenic character (Sharma, 1987; Iyer & Subramanyam, 1987). Iyer (1991) studied inheritance of flesh color in Alphonso and Neelum cvs. of mango and found that light yellow color is dominant over orange yellow. Iyer and Subramanyam (1979) found bunch bearing and presence of beak on the mango fruit as dominant character. Bacterial canker inheritance is cytoplasmic in 'Neelum' while the mango malformation susceptibility appears to be dominant (Sharma & Majumder, 1988a).

PERSPECTIVE OF BREEDING IN MANGO

The opportunity for breeding improvement in the mango is significant and challenging. There is a lot more varietal wealth available but certain inherent constraints are involved like: long juvenility, high clonal heterozygocity, one seed per fruit, recalcitrant seeds, polyembryony, early post-zygotic auto-incompatibility and large area requirement

for assessment of hybrids. On the other hand, wide range of diversity and ease of vegetative hybrid propagation are the advantages for the breeders. There are very few man made commercially important hybrids. Mango development is mostly based on the selection of clones/chance seedlings. These selections were made for fruit quality only. Seedling screening from known mother plants is another way of selection for better lines. Modern age requirements of a good cultivar involve: dwarfness, precocity, profuse and regular bearing, attractive, good sized and quality fruit, absence of physiological disorders, disease and pest resistance and improved shelf life etc. As far as the improvement of the rootstock is concerned, the main features desired are polyembryony, dwarfness, tolerance to adverse soil (high pH & soil type etc.) and climatic conditions and scion compatibility.

Now, more comprehensive knowledge about the phenology, inheritance patterns of mango and advanced techniques for hybridization is available. Many environmental and physiological factors related to the undesirable character of mango varieties (irregular bearing, susceptibility to diseases and pests, poor eating and keeping quality, etc.) are closely controlled by genes. To overcome these, plant breeding can play an important role and work should be done in three directions as introduction, selection and hybridisation. Hybrid populations can be managed in a better way and the development of the genetic markers has further reduced the uncertainty in breeding mango.

Breeding methods. There are two main types of mango the Indian types with monoembryonic seeds and susceptible to anthracnose while the Indo-Chinese types with polyembryonic seeds and are tolerant to anthracnose (Lespinasse & Frédéric, 1998). Breeding methods involve: selection from open pollinated seedlings occurring naturally, controlled pollinations (hand pollination of limited flowers on large number of panicles), enclosing self-incompatible female and male parents and cross pollinating with houseflies, maintaining hybrid populations by grafting scions on established plants, and pre-selection of mango hybrids to discriminate undesired material. Sharma *et al*. (1972) found emergence of new growth flushes, with fruiting or immediately after harvest, as an indication of regular bearing. Higher phloem to xylem ratio is associated with dwarfing. Genotypes with ratio more than one tend to be least vigorous while those with ratio less than 0.6 are more vigorous (Kurian & Iyer, 1992). Most of the hybrids arise from selection among two varieties or primary hybrids and no recurrent selection is reported. Selection from natural mutants for important agronomical traits (such as precocity, yield, regular bearing and resistance to diseases) might be improved by sport selection.

Mukherjee *et al*. (1968) stated that breeding results has not been encouraging and hand crossing is remarkably unrewarding. The handicaps involve long life cycle and occurrence of polyembryony. Iyer and Subramanyam (1992) carried out breeding of mango cv. Alphonso to overcome the physiological disorder of spongy tissue formation. Alphonso was crossed with seedlings from natural cross-pollination. In Florida, following intensive introduction by the end of the 19th century, some important export varieties have resulted from seedlings derived from open pollinated (or not) identified mother plants. Today, most of the new Indian hybrids are regular bearing, with good quality fruits (free of spongy tissue) and attractive skin color. All the hybrids have higher pulp yield and possessed lower peel, stone and fiber content. The adoption of the new varieties is still fairly low. In Israel, seedlings were selected for peel color, fruit quality and favorable harvesting season. Regarding rootstocks resistant, or tolerance to calcareous and high salinity soil, several monoembryonic and polyembryonic hybrids have been identified but none performed better than '13-1', the currently preferred rootstock in Israel. In South Africa, the outstanding new variety "Heidi" was released in 1990 and is commercialized internationally.

Mango breeding in Israel has resulted in the identification of 15 hybrids. In Australia, very promising progenies were obtained from crosses between the clone 'Kensington' (good flavour) and 'Sensation' (bringing favorable agronomic traits). In South Africa, genetic improvement was achieved by selection and four new cultivars were released in 1990's. As a result of the implementation of controlled pollinations, good evaluation and selection procedures in the field, new outstanding hybrids of mango were released. According to Israeli breeders, mango breeding is still in its infancy and considerable genetic and varietal progress should be expected from long term-integrated programmes. Mango breeders will have to take into account the improved knowledge of inheritance of specific characters (recessivity for polyembryony, dwarfism, regular bearing and precocity). The recent findings on heritability suggest that the additive genetic variance was small and non-significant; whereas, the non-additive variance was large and significant in most of the traits, which should also be taken into consideration.

Role of wild species in mango breeding. Fairchild (1948) observed that crosses between five stamened and Indian mango could produce hybrids with better pollinating quality. Bompard (1993) stated that *M. laurina* could be used to incorporate resistance to anthracnose. There are certain wild cultivars of mango i.e., *M. orophila* and *M. dongnaiensis* both described from Malaysia and Vietnam respectively, that are restricted to mountain forests above sea level. These could help to start mango cultivation even in the Mediterranean areas. Other wild species have certain specific characters like *M. mangifica* is fibreless, *M. rufocostat* and *M. swintonioides* have off-season bearing habit, *M. pajang* and *M. foetida* have good quality fruits and *M. casturi* from *S. kalimanta* is prolific bearer with small black sweet fruit. These species may be helpful to enhance the existing gene pool and to develop new hybrids in mango

(Bompard, 1993; Kostermans & Bompard, 1993). *M. altissima* unaffected by hoppers, tip and seed borers (Angeles, 1991).

Mutations. Bud mutants occur frequently and are a valuable source of variation. Albino mutant occurrence is quite frequent in mango seedlings and in certain shoots in mature trees. There are only two cases of somatic mutants yielding new cvs. 'The Davis' sport of 'Haden' (Young & Ledin, 1954) and 'Rosica' bud mutant of Peruvian cultivar 'Rosado de Ica' (Medina, 1977). The mutants are high yielding, regular bearing and seedy.

Induced mutations by radiations were first used by Siddiqui *et al*. (1966). He exposed dormant buds of Langra to gamma radiations and grafted on one-year-old seedlings. Bud graft exposed to 3.0 kR of radiations bore heavier and larger fruits than control. Singh and Chadha (1981) located four superior clones from orchards of Dashehari while Singh *et al*. (1985) isolated high yielding clones from 'Langra' orchards. Sharma and Majumdar (1988b) irradiated bud sticks of Dashehari with chemical mutagens (EMS and NMU) and top worked them on to 10 years old seedlings. The mutants showed dwarfness, changes in shape, leaf serration and TSS. Mutations can be successfully propagated asexually. The techniques used need to be perfected in mango to make mutation breeding more purposeful.

Breeding problems can be minimized by minimizing the high fruit drop, shortening juvenility and polyembryony dilemma for the breeder and asset in rootstock propagation. Isozymes are used to identify the zygotic seedling from the nucellar one's as the nucellar seedling should have same isozyme alleles as that of the maternal parent. (Schnell & Knight, 1992; Truscott, 1992; Degani *et al*., 1992; 1993). The mango fruiting season for South Florida is very short (from mid-June to mid-August). Extending the fruit season could provide opportunities for increased production and more favorable marketing conditions for growers. One-way to accomplish this is to modify flowering time. Schnell *et al.* (1999) studied flowering in mango to prolong the harvest season. Three variables (days to bloom, days in bloom and days in bloom and fruit) were measured on eight varieties for six years. Replicate trees of the same variety reacted very similarly within a given year indicating that large replicated plantings are not necessary to study these variables. This is important as many of the mango varieties in the germplasm collection in South Florida are represented by one or two mature trees only. Repeatability of the flower phenology characters was high, indicating that much of the variation is heritable and useful for further breeding. In future, better efficiency in mango breeding will have to rely on planned hybridization assisted by the new tools offered by biotechnologies. The recent emergence of molecular markers and the application of somatic embryogenesis to genetic transformation will enable the integration of specific genes from cultivated varieties or wild species into popular current cultivars.

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