

Biennial bearing of mango

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THE terms alternate, biennial, intermittent and irregular bearing for mango are usually used by research workers. These terms signify the tendency for mango trees to bear a heavy crop in one year and very little or no crop in the next year. All these terms may broadly be grouped in one general term, viz., "periodicity in cropping".

There are certain varieties of seedling mango which are of shy bearing habit. The terms covering "periodicity in cropping" should not be confused with "shy bearer" or "unfruitfulness", as mango trees are known as shy bearers when they produce a very small amount of fruits instead of the total crop, which should be produced in accordance with proportionate size of tree. On the other hand, they are said to be unfruitful when they produce very little or no crop at all due to factors like unsuitable climate and too humid an atmosphere all the year round.

Trees having a biennial habit bear a heavy crop in one year which is termed "on year" while in the next they bear very little or no crop which is termed "off year". It is a proven fact that this tendency of "on" and "off" remains so and goes on continuously unless the habit is altered by external factors like the occurrence of frost, hail, disease, pests and inclement weather at time of flowering.

For the sound development of the mango industry the production of a reasonably regular crop every year is of prime importance. This is why this review has been prepared to give research workers and orchardists an understanding of the problem.

The discussion of the different factors affecting mango cropping and possible control measures is grouped under different heads in the following review.

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1. *Biennial Bearing Rhythm*.—As early as in the year 1590 Abdul Fazal while giving an account of mango fruit in *Ain-i-Akbari* mentioned that some trees yielded a heavy crop in a year and light one in the next, while others produced one year and not in the following year. Afterwards it was confirmed that mango trees did not bear a heavy crop only in every alternate year and they produce a poor crop in the intervening year (23). Alternate bearing was found to occur with most trees, but there were interesting exceptions specially among Pirie mango trees. Some workers believe that bearing habit of mango is an acquired character and can be corrected by resorting to proper cultural practices (178). All the factors—cultural practices, growth, flowering, fruit set, and total yield—should be taken into account for bearing habit (120). Mango is a heterozygous fruit and its cropping pattern depends upon the several factors (7, 10, 60, 94, 144, 152, 205).

The mango tree starts the biennial bearing rhythm even from its early stage of fruiting for the first time (90, 157, 160, 208). It was also reported that biennial bearing rhythm sets in at the age of 10 years or more (74). However, Gandhi (43), Singh and Khan (174) reported that young mango bears a regular crop, although not of the optimum quantity every year and later on starts biennial bearing when the trees attain the age of 10 or 12 years.

The measurement of biennial bearing habit in the mango varieties is a very difficult task. It can be assessed through the measurement of the yield of a certain variety on the successive year yield basis for a period of several years. But this scale of measurement seems not to be very accurate for the different sets of trees (11). Hoblyn *et al.* (61) evolved a method to assess the intensity of biennial bearing habit and it has been fully described by Singh (177) for measuring the intensity of biennial bearing in mango. The intensity is calculated for each pair of years by the formula given below.

$$I = \frac{\text{DIFFERENCE BETWEEN SUCCESSIVE YIELDS}}{\text{SUM OF SUCCESSIVE YIELDS.}}$$

Where 'I' stands for intensity of the whole period for a particular tree.

2. *Role Growth Cycle*.—Growth cycle plays an important role in fruiting of mango (168, 198). Vegetative shoots are produced in different flushes and after attaining a certain age they give rise to the

reproductive flush for bearing. These growth flushes emerge in different months in the different parts of the country (43, 143, 207). Burns and Prayag (24) reported that the cold weather, hot weather and rainy season growths produce the inflorescence in western parts of India. Krishnamurthi *et al.* (80) reported 5 cycles of shoot growth in Dashehari and Chausa where main growth flush took place in March to May and 8 to 10 months old shoots were found better to produce better panicles than the younger ones.

Galang and Laza (40) reported that shoots had to attain a certain length, girth, number and size of leaves for producing panicles. However, Singh (200) observed no relationship between length, girth and number of leaves per shoot regarding the flower bud formation as the fruit bud differentiation can take place from any point of the tree and its stimulation is irrespective of the size and maturity of the shoots.

3. *Potentiality of Shoot or Maturity.*—Shoots which appeared early after shedding their blossoms and having desirable extension of growths, have the greater potential to produce panicles in the coming season (21, 114, 118). Mango variety Neelum and Swarnrekha gave rise to shoots as late as October with the potentiality to produce flowers in February (28). However, it has been emphasized that the mango shoots must cease their growths early in order to give rise to flowers in the coming season (72, 115, 164, 173, 175). Shoots which appeared in February-May flush attained the physiological maturity for producing the flower panicles.

Previously the effect of shoot maturity on flowering was emphasized (40, 73, 89, 143, 189) but recently some evidences are found against this theory; at least in the case of regular bearing varieties, where shoot maturity is not at all a pre-requisite to flowering (44) and the flower formation is governed by the 'off' and 'on' year conditions rather than the age of shoots (178). Singh (200) reported that the types of shoots extended and unextended in biennial bearing varieties form the flower buds in the 'on' year while in 'off' year there is no fruit bud formation in both the types of shoots. 'Off' and 'on' year phase seemed to determine the formation of fruit buds in mango through some special mechanism, in spite of the shoot growth (209).

4. *Fruit Bud Differentiation.*—Fruit bud differentiation is a pre-requisite stage for the development of a panicle. Chandler (25)

reported that it was not certain to conclude how long a bud sets in a condition that it may be caused to lead to the fruit bud differentiation, while Singh (196) found that the fruit bud differentiation and development is a continuous phase and takes a period of about one month. However, Reece *et al.* (139) observed that differentiation begins within a very short period of the development of terminal buds in mango variety Haden and the process of differentiation goes on continuously with the time of bud expansion.

Lanuza (82) observed no definite floral characteristic to distinguish between a dormant flower and a vegetative bud, while Juliano and Cuevas (69) found that floral parts develop in the order of calyx, corolla, stamens, pistile and finally ovules. Histological and morphological studies made by Singh (199) revealed a clear distinction between flower and a vegetative bud development and its different organs in the order of calyx, corolla, stamen-staminodes, carpel and disc except Baramasi variety.

5. *Time of Fruit Bud Differentiation.*—The times of fruit bud differentiation vary in the different parts of the country (155, 156, 182, 192). In Florida fruit bud differentiation took place in the month of October and November (107, 139, 219). Dry summers are more conducive to flower bud formation in the wet zones (63). Time of fruit bud differentiation ranges from middle of August to end of October in the Punjab (76, 105, 106), Sen and Malik (164) found the critical period of flower bud differentiation in October and first half of November in Bihar conditions while it was noticed after mid-November and reached to its peak by mid-December for Himsagar and by the end of December for Langra in Bengal conditions (162).

6. *Physiological Aspects.*—Flowering is a pre-requisite to fruiting and fruit bud differentiation is pre-requisite to flowering. Fruiting depends on the nutritional status of the particular shoot along with the other factors. Carbohydrate-nitrogen ratios and their increase or decrease content in the shoots play an important role in bearing of mango. For formation of reproductive flush, a mature shoot should have its carbohydrate content much greater in proportion to nitrogen but when nitrogen is more than carbohydrates the shoot will certainly produce vegetative flush. (160).

The problem of biennial bearing should be tackled from the point the physiological changes connected with the emergence of panicles (14). Seasonal variations in the carbohydrate-nitrogen content were

studied in Langra shoots by Naik and Shah (117) for the first time. A sharp rise in carbohydrate content in the mango shoots in the period from October to November was reported which was considered favourable for fruit bud differentiation in the mango (89, 166).

Reece *et al.* (138) reported that a flower inducing hormone determines the course of fruit bud differentiation of the tissue. Singh (183, 202) studied the nutritional, biochemical and chemical composition factors of the shoots and found a high content of starch and total carbohydrates at the time of fruit bud differentiation and these appeared to favour the flower-bud formation.

7. *Tree Vigour and Nutrition.*—It is an accepted fact that in the 'on' year the fruits are generally harvested in June-July and thus the trees exhaust their reserve, further to give rise to new shoot growth for bearing fruits in the 'off' year, and the trees cannot replace their reserves since there cannot grow as long as there are fruits on them (11,43). Popenoe (130) observed that crop failures sometimes occur due to the variations of soil moistures and to some extent of food supply, while Roy *et al.* (145) reported that the biennial bearing is caused due to nutritional deficiency which may be brought into order by application of manures. In Florida, Young (241) found that the content of internal nutrition factors and moistures were not the main cause of unfruitfulness in mango variety Haden.

Singh (180), in chemical composition studies of the bearing and non-bearing shoots, found that bearing shoots had higher nutrient value than the non-bearing ones in respect of CaO and MgO in Dashehari and CaO, MgO, N and P_2O_5 in Langra and concluded that biennial bearing in mango is initiated by some factors other than mineral nutrients. Nutritional factor of the shoots cannot be correlated with the fruit bud formation (182), whereas, higher starch reserve, total carbohydrates content and carbohydrate-nitrogen ratio in the mango shoots at the time of fruit bud differentiation was recorded. Singh (202) observed a high content of dry matter linked up with the period of fruit bud differentiation which appeared due to the accumulation of carbohydrates.

Singh (183) reported that biennial bearing of mango is a varietal characteristic and it comprises of strongly biennial, partial biennial, regular and extra regular. Singh (184) further reported that trees of regular or extra regular varieties are less vigorous than the biennial ones and inferred that vigour is a measure of the biennial bearing

habit of the variety and more vigorous in the variety the more biennial tendency it has. It was found that soil group also affected the vigour and cropping behaviour of mango tree (66, 79).

8. Role of Auxins :—

(a) *Formation of auxins in leaf.*—Auxins are produced in the leaves which are responsible for fruit bud differentiation in mango (138, 139, 153, 156, 189). Chandler (26) is of opinion that hormone induces flowering in plants and the sources of hormone are leaves or some precursor formed in the leaves, then leaf surface rather than accumulation of carbohydrates might be having dominant influence on flowering and further he reported that if hormone or some such substance is necessary for induction of the flower bud, then a fairly definite age and physiological condition of leaf may be necessary for it to induce flowering. Singh *et al.* (206) and Thiman (223) indicated that newly emerged leaves may generate the flowering stimulus in shoots of the regular bearing varieties like Neelum and Romani. Flowering depends on some sort of flowering stimulus transmitted by the leaves to the apical or axillary bud (181). Singh (182) advocated a hypothesis that flower induction can take place only when cell division has started and that a flower inducing hormone plays no part in the initiation of growth but its presence in sufficient amount at the beginning of growth determines the course of differentiation of the tissue in the axillary buds.

Plant growth regulators affect the flowering of mango (163). Singh (186) sprayed G A (50,100 ppm) and M H (0.4-0. 6%) and observed that a crop might be taken by the use of G A even in the 'off' year. Singh and Singh (209) tried NAA, 2, 4, 5-T 2, 4-D (25-500 ppm) and MH (0.05-5. 5%) in Punjab and found that 2, 4, 5-T significantly reduced fruit yield in 'on' year with only small compensation in the succeeding 'off' year while NAA, 2, 4-D and MH showed very little effect on panicle emergence on new shoot growth during the following 'on' year.

(b) *Movement of Auxins.*—Flower inducing substance is generally transmitted from the leaves to the axillary buds when inhibiting effect of the terminal bud is removed (138, 139, 156). Singh (181) observed that the flowering hormone used to move in all the directions in stock and by its effect seedlings flower even in the absence of leaves on them. It has been shown that a young mango seedling can be made to flower and fruit, if grafted to a comparable stock of the bearing tree and given additional treatment of defoliation along with the girdling of the scion shoot below the union.

9. *Cytological and Genetical Causes*.—Regular bearing varieties can be evolved to overcome the biennial bearing tendency in mango (19, 91, 100, 114, 190). Besides environmental and physiological factors related to biennial bearing of mango varieties, this factor is controlled by genetic factors. Varieties Dalma, Sukul and others have been found to be regular bearers even under the same soil and climatic conditions in which the majority of them show a characteristic of periodicity of bearing (4, 6, 22, 143, 183, 220). Naik (109) reported that trees of some particular variety in an orchard may be low yielding or sterile while other trees of the same variety in a new orchard may bear heavily.

10. *Sex Ratio*.—The sex ratio plays an important role in determining the crop yield and the varieties producing maximum perfect flowers are usually more prolific bearers (214). In mango, pollination is essential for fruit setting and it is mainly performed by insects (31, 93). Bi-jhouwer (17), Mukherjee (102), Wagle (230) and Singh (195) reported that 50 per cent or more of the perfect flowers remain unpollinated in nature while Spancer and Kennard (217) observed the low fruit set due to failure of gynaecium to develop properly and reduction in the viability of the small quantity of pollen produced by low humidity, high temperature and bright sunlight. The variations were observed in the distribution of perfect flowers on the different portions of panicles, and low or high ratio which lead to the low fruit set in mango (8, 16, 56, 87, 135, 190, 227). However, Naik *et al.* (113) found that many of the flowers are not pollinated at all and the restricted pollinations have adverse effect on the yield. Maheshwari (86) in North India and Popenoe (129) in Florida found that the percentage of flowers which form mature fruits was less than one in mango. Mukherjee (103) found that the failure of pollen germination on stigma might act adversely whereas Naik and Rao (116) obtained better fruit setting by the varietal combinations in pollination in case of South Indian varieties. The essential reproductive organs of the mango flower were observed quite normal and healthy by Mukherjee (99). But Singh (195) reported various degrees of ovule disintegration, while in Florida, Young (24) observed degeneration of embryo sac and in Philippines Dudgeon (35) observed the loss in fruit set caused by flowers having abortive pistile.

On the basis of sex ratio variety Simmonds and Summer Bahist Chausa were reported for prolific bearing habit (215). Similarly, Ledin (83) reported that polyembryonic-Philippine mangoes are reliable bearers and generally produce heavy yields, often fruiting in clusters. The high percentage of perfect flowers (40 to 80%) probably accounts for the heavy bearing.

11. *Mixed Panicle*.—Production of mixed panicles is favourable for regular bearing in mango (90). Mango varieties showing annual bearing tendency produce a high proportion of mixed panicles than the irregular ones (26, 157). Singh (201) and Randhawa and Damodaran (134) observed mixed panicles in Baramasi and Chausa, Dashehari and Krishna Bhog varieties.

12. *Climatic Factors*.—Climatic conditions may be taken into consideration as some factors which cause the biennial bearing in mango and play an important role in its cropping (27, 33, 104, 147). Climatic factors are associated with the biennial bearing of mango in two ways, either by directly damaging the fruit buds and crop or by creating such conditions which indirectly destroy the flower or fruit. A dry season, immediately preceeding the period of blossom emergence is helpful for early cessation of vegetative growth which is a prerequisite for flowering in mango (52, 62, 93, 111). It was found that, for optimum cultivation of mango, the absence of very low temperature is essential (5, 9, 45, 119).

The drop in temperature during the nights at bloom period inhibits the growth of pollen tube (1, 242, 243). Singh (188) found that when air temperature dropped to 31°F, fruit buds at all stages killed out, and bloom was completely damaged. Formation of buds is affected by a prolonged cold season (57). Frost showed a considerable effect on biennial bearing in the varieties Singhara and Vijai Raogarh (203). Harris (55) observed that the trees often flower profusely but fail to set fruit as the pollen, owing to excessive humidity is never in a suitable condition for cross pollination. Diseases like Blossom Blight during certain years are chiefly responsible for the failure of crop and thus induce irregular bearing (178). In Gautemala, almost all the blossoms were attacked during rainy season (122), while in Florida, disease becomes a limiting factor in rainy or foggy season (235). Insect pests and diseases play an important role for mango drop and they cause severe damage and induce irregular bearing (12, 95, 96, 133, 155). Insects caused 60 per cent to total failure of crop in India (210) and South Africa (6).

13. Control of biennial bearing—

(i) *Cultural Practices*. —There is no doubt that planned orchard management plays an effective role for mango cropping. Intensity of alternate bearing can be controlled by a considerable extent with proper planning and orchard management (221, 228). Cultural practices like mulching, cover cropping, irrigation, types of fertilizers and methods of their application also affect the absorption of nutrients and cropping of the mango (59, 85, 91, 144, 225).

Singh (180) suggested that in India mango should be manured during the pre-bloom period also, as alternate bearers are supposed to suffer from malnutrition (46, 88, 145). Ruehle (149, 150) suggested application of N or N and K at the appearance of flower panicles first, followed 3 or 4 weeks later and again during the summer by complete N P K mixtures, as N controls the uptake of other elements and determines growth and shows the greatest effect in combination with P and K. In 'on' years the Ammonium sulphate dose should be doubled to force July-August shoots which mature and flower during the successive 'off' year (92,160). Ledin and Malcolm (84) found that Haden and Zill varieties, fertilized in winter, spring and summer continued to yield more than when fertilized in spring, summer and autumn. Attempts should be made for inducing sufficient vegetative growth early in season of 'on' year by cultural practices (24, 43, 71).

Cultural practices such as root pruning, applications of salt and incision in the bark are also useful (75, 154, 167). Firminger (37) is of view that roots should be exposed for 2-3 weeks in November and covered with fresh earth and manure in December to have some use on biennial bearing habit. A favourable response of cultural practices on flowering and fruiting have been recommended for a good crop as they encounter the biennial bearing in mango (15, 27, 29, 34, 36, 38, 39, 54, 97, 108, 123, 126, 127, 131, 140, 141, 158, 239, 240). Mango crop are some times, severely damaged by insect pest and diseases etc. in the 'on' year and with the result the new shoots appear and give rise to panicles in the next year (13, 77, 110, 121, 137, 211, 212, 213, 233). However, Singh (184) concluded that biennial bearing habit of mango cannot be prevented by restoring to manuring, irrigation, pruning and control of pests and emphasized that the real cause of biennial bearing is not yet known and till it is fully discovered, no 'hit and miss' method is likely to solve the problem ; therefore the first attempt of the scientists, engaged in this field towards the control of this phenomenon will be to determine the exact cause of fruit bud differentiation.

(ii) *Deblossoming*.—Deblossoming early in the season induces the shoots to grow in the same season and produces fruits in the coming season (66, 173, 175). The response to deblossoming appears a varietal feature as Dashehari responds fairly while Langra fails to show the same response (176, 182, 204).

Singh (179) observed that half deblossoming of mango trees as an orchard practice is useful only to the extent of uniform spread of the biennial bearing orchard while Sen (161) advocated that deblossoming, defruiting and branch ringing in 'off' year have response to bearing habit of mango

(iii) *Defoliation and Decapitation*.—Rao and Muthuswamy (136) observed in Mulgoa variety that removal of scion shoots grafted showed its effect as of girdling and decapitating for inducing the axillary buds to differentiate the inflorescence. Defoliation may prove useful as a corrective measure for regulating the bearing in mango as it is cheaper and easier to practice (178,200).

(iv) *Ringling and girdling*.—Ringling or girdling involves the removal of a ring or bark from the trunk or branches of a tree (88) and this has been practiced for many years particularly in Europe as a means of inducing flower formation (50). Flowering was increased substantially by girdling in October (48, 159). Ringling raised C/N ratio of the branches to force them to flower in 'off' year, and practice was recommended for best results in early August (4). Wagle (229, 231) recommended girdling as a means to obtain flowering in mango.

(v) *Hybridization*.—There is no doubt that periodicity exists in most of the varieties and may be of inherent character, and it may be overcome by evolving new varieties through hybridization (26, 78, 98, 169, 170, 191, 222). Singh (185) suggested that regular bearing species of *mangifera* should be introduced from other countries of the world and interspecific hybridization should be taken up. In North America alone, above 70 research stations were engaged in fruit breeding work. Several new fruit varieties and hybrids have been evolved which have given better performance by way of higher yield, superior fruit quality and resistance to disease and pests (3). In Cuba, Popenoe (128) reports the possibility that occasionally variations may be found due to cross pollination in case of polyembryonic varieties of mango. Singh (207) reports that the hormone are generated by the genes. The remedy will therefore actually lie in regaining the old genetic setup which determines balanced growth and fruiting from season to season and the best way is the evolution of new plant forms through the cross breeding of existing irregularly bearing varieties with the regular ones.

In India as early as in 1885, Lahiri (81) reported that most of the famous varieties of Murshidabad mango had been evolved by cross pollination of Maldha and Choon Khali varieties. Genus *Mangifera* has allopolyploid nature (101). Taking the base of cytology, Mukherjee (100) concluded that primitive type or types which gave rise to mango varieties originated through allopolyploidy, most probably through amphidiploidy and the further differentiation of the various varieties has taken place primarily through gene mutation (65). Singh and Singh (1940), Roy and Visweswariya (142) are also of opinion that

inter-varietal hybridization in nature may be another important factor in the production of new mango varieties. Roy *et al.* (146) recorded even resistance in the hybrid to attack of fruit fly and borer. New early or late maturing mango of high quality with good keeping quality as well as having regular bearing tendency can be produced through hybridization (5, 42, 68, 70, 125, 238). Of 39 varieties originated in Florida, a few have the desirable characteristics of commercial varieties (151). Attempts were made in West Indies to combine the good qualities of Indian Mango with the indigenous types by artificially crossing them (20). In India Burns and Prayag (24) were the first to report artificial crosses from Poona. Naik (112). Sen *et al.* (165), Singh (193), Sturrock (218), Traub and Robinson (224) and Young and Ledin (244) attempted crossing and have produced a few hybrids of promise. Planned hybridization work in India was organized at Kodur (112), Loyalpur (148, 172), Sabour (165) and Saharanpur (197). Two promising hybrids, one each of the cross, Neelum x Hymayuddin and Swarnrekha x Jahangir have been evolved at Kodur. Mahumud Bahar and Prabha Shankar hybrids have been evolved from the cross of Bombay and Kalapady at Sabour (146), which have been appealing characters. At Saharanpur, the hybrids of Dashehari and Romani have been evolved which combined in, the good qualities and they are under observations.

Manila from Mexico, Cecil from Cuba, Cambodian and Saigon from Indochina were introduced to Florida : all are polyembryonic and are generally better producers than the Indian mangoes and some like Saigon types are regular bearers and are resistant to anthracnose. The Edward and Simmonds are considered crosses of Haden x Carabao and Semini which is a cross between Saigon-Amini made by Edward-Simmonds of the United States, Plants Introduction Garden in Miami in 1920 (83).

(vi) *Smudging*.—The practice of smudging, depending upon climatic conditions, has been reported as a means to induce flowering. The mango trees are smudged day and night for a week and thereafter in the morning and evening for a month's time. suitable period for smudging is October and December. Smudging heat, not the smoke, helped to induce flowering in non-bearing trees (2, 18, 32, 49, 82, 236, 237). A well planned, research project should be carried out to assess the response of smudging treatments to mango trees (28, 41, 91).

(vii) *Propagation*.—Regular bearing varieties can also be obtained through propagation (30, 31, 47, 132). Role of polyembryony has a good deal of scope and stock from polyembryonic varieties should be

taken for the regular bearing varieties (64). In Florida, Brooks, Haden, Eldon, and Smith varieties have been evolved and in Ceylon stocks of certain varieties have been selected for propagation. Besides the utilization of apogamic seedlings has also been recommended by Webber and degree of apogamy in Peach variety is about 100 per cent which is valuable for vegetative propagation (234).

(viii) *Grafting and double grafting*.—The desired change in the bearing habit of mango can be sought through the alternative method of stionic studies (234). Among the root stocks may also be included mango species other than the *Indica* as may be observed to possess the desirable characteristics of growth and regularity in the bearing (207). It has been reported that wild mango Pulima is a very hardy, vigorous one and the trees grafted on it bear profusely and regularly in Ceylon (53). Similarly, Grant and Williams (51) found that 'Thalapatt' and 'Saing' varieties have been found to be very good for the grafting of Indian varieties in Burma. Double grafting is believed to suppress excessive vegetative growth of the tree, making it a dwarf and hastening and regulating the bearing. Double worked trees are generally of dwarf habit (28, 58). Singh (182) also observed that dwarf mango trees have generally less tendency towards alternation. This field also needs more intensive research than it has so far received (171).

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