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Review Article

Studies on fruit-bud differentiation in Mango (*Mangifera indica*)

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The time of fruit-bud-differentiation in mango is known to be governed by local weather conditions, which varies from place to place. To some extent, it also varies with varieties grown under the same climatic conditions. The knowledge of the time of fruit-bud-differentiation under a particular set of climatic conditions for a given variety would enable the orchardists to schedule the manuring, irrigation and other cultural operations to have better yield. The fruit-bud-differentiation is a crucial event in the growth and development of mango, as it marks the change in partitioning and transport of metabolites from source to sink between the vegetative and reproductive organs which are governed by the growth hormones. The physiological and biochemical factors governing fruit-bud-differentiation in mango have not been adequately studied. Little is known about the role of naturally occurring growth substances and other metabolites involved in fruit-bud-differentiation. Need for such studies is all the more important, since these naturally occurring growth substances are now recognized as important factors controlling the ontogeny of flowering in higher plants.

Key words: Fruit bud differentiation, time of fruit bud differentiation, hormonal control of flowering, biennial flowering

This review researches on fruit-bud-differentiation studies. India has contributed a lot on these aspects. Although, the work on this problem was initiated about five decades ago, sufficient information is not available on fruit-bud-differentiation and the associated biochemical changes. Environmental links to floral induction and evocation are generally well understood. By manipulating different factors, flowering can be enhanced or regulated in alternate bearing varieties up to a certain extent. Salient features of the work done on fruit bud differentiation aspects are reviewed under.

1. Morphological and histological changes associated with fruit-bud-differentiations

Initiation of fruit buds in mango is marked by the changes that take place at the growing apex of the shoot. Singh (1958) made a comprehensive study on the morphological and histological changes associated with differentiation of flower buds in mango at Saharanpur, Uttar Pradesh and his study may be summarized as below.

Basically, both vegetative and fruit buds are alike in external appearance, being green with brownish tip forward of partially dried scales. The development changes that lead to the formation of fruit buds may be broadly divided into six stages.

Stage I

The apical bud became dome shaped followed by drying of outer scales and the inner scales appear flesh finger-like projections.

Stage II

By first or second week of December under Saharanpur conditions, the main axis got elongated accompanied by slight broadening of the axil of scales. The apex started broadening and assumed round space. This was followed by development of broad conical protuberances in the axil of scales, which is an indication of fruit-bud-differentiation.

Stage III

By the beginning of third week of December, the flower bud got protruded with the further elongation of the main axis, which became more conical at the distal end. It appeared multi-lobed due to the development of primordial of the primary branches of panicle slightly below the apex in the axil of bracts. The side protuberances also became multi-lobed due to the primordial of the secondary branches. The scales became less compact and were elongated.

Stage IV

By fourth week of December to the first week of January, the flower bud became conical measuring about one cm in length. All the old scales get withered and distinct primary branches along with elongation of axis followed by secondary branches are formed. The lobbing of secondary branches indicated further branching formation of floral primordial.

Stage V

A few days after the formation of the inflorescence primordium, the surrounding scale started opening out which marked the 'bud break' stage

Stage VI

By second or third week of January, the bud reached the 'bud burst' stage, which was characterized by further loosening of the scales and the elongation of the floral axis with appreciable growth of primary and secondary branches of the panicle.

Developmental Stages of vegetative buds

The vegetative bud showed activity only in last fortnight of February and histologically hardly any difference was noticed between the different stages of development. The main axis got slightly elongated and thickened, the old scales at the basal end got separated and dried up, more whorls of young and active scales surrounded the growing apex. At the time of 'bud break', the vegetative bud was comparatively narrower, more sharply pointed than the fruit bud. At 'bud burst', the needle-like scales at the apical end and the basal scales unfolded.

2. Factors governing fruit-bud-differentiation.

2a. Period /Time of fruit bud differentiation

There is considerable variation reported with regard to the actual time of flower-bud-initiation in mango since it is dependent upon the climatic conditions, particularly the fluctuations in temperature, the previous season crop load on the tree and the variety. The studies on fruit-bud-differentiation and development in mango have been done widely in India, Florida (USA) and the Philippines.

Mustard and Lynch (1946) and Sturrock (1934) reported that October to be the time of flower-bud-differentiation in mango under Florida conditions. Under the same Florida condition, Reece *et al.*, (1946) found that differentiation of the inflorescence begin within a very short period before the expansion of the terminal buds from December to February in the 'Haden' mango and the process continued during the period of bud expansion.

In India, also a lot of controversies do exist with regard to the time of flower-bud-differentiation. The time of flower-bud-differentiation was reported to be during October to December by different workers. Mussahib-Ud-din (1946), Sen and Mallik (1941) opined that for all practical purposes, the month of October and first half of November, *i.e.* a period of about five to six weeks immediately preceding the period of cessation of growth in November to December may be taken as the critical time for fruit-bud-differentiation under Sabour conditions. Singh (1958) studied the morphological and histological changes of fruit-bud-differentiation in some mango varieties and reported that the last week of December was the critical time for flower-bud-differentiation under Shaharanpur conditions. He also did not find any period of dormancy between the time of fruit-bud-differentiation and that of inflorescence expansion. He reported that the 'Baramasi' behaved peculiarly with regard to the critical time of fruit-bud-differentiation and this cultivar sometimes showed the critical time of fruit-bud-differentiation twice a year and in certain years it was just only once. In general, the differentiation period for the 'Baramasi' was during May to June and September to October and this appeared to be its hereditary character. However, Khan (1960) found this period extends from mid August to the end of October for all flushes except in case of July flush in which differentiation took place in November.

Ravishankar et al., (1979) studied the time of fruit-bud-differentiation in 'Alphonso' mango. The fruit bud differentiation started in early October and reached peak by mid-November in the mild tropical rainy climate of Dharwad in India. They observed four developmental stages of fruit buds based on histological and morphological characters.

Lin-Shuzeng and Chen-Zongwei (1981) conducted the FBD studies in two mango cultivars in Hanan Island of china. The FBD started in the second half of November and reached a peak in the first half of December in the cultivar 'Qingpi.' For another cultivar called 'Qiumang', it started in the mid December and reached a peak in the mid of January. Osuna-Enciso and Engleman (2000) studied the time of FBD in the 'Manila' mango cultivar in Mexico. They found that the floral initiation started in the first two weeks of February and was completed in four to six weeks later. Humayun and Babu (2002) studied the time of fruit-bud-differentiation in six varieties of mango in Andhra Pradesh. They found that the fruit bud differentiation commenced in 3rd week of September and was completed by the 3rd week of November. However, the on set of FBD and the peaks of differentiation varied among the cultivars studied.

2b. Climatic factor governing fruit bud differentiation

Sen and Mallik (1941) working under Sabour conditions of Bihar reported that there was a sharp change in climatic conditions at the end of September especially with the advent of cold and dry weather appeared to influence fruit bud differentiation. Singh (1960) reported that neither the high humidity and rain at the time of bloom nor the late rains appeared to influence fruit-bud-differentiation. However according to Chacko and Randhawa (1971) heavy rains during the critical time of flower-bud-intiation stimulated vegetative growth at the expense of flowering. In places like Kerala, where rainfall is heavy, mango flowered sparsely and erratically. Singh (1961) also observed that the mango trees in extreme humid place and under mild climatic conditions remained unfruitful owing to their increased tendency towards vegetative growth. A low temperature resulting in frost was reported to have effected the fruit-bud formation indirectly in the cultivars 'Singharha' and 'Vijai Rao Garh'. He further observed that the regular bearing cultivars remained unaffected and no definite relation between the temperature and the extent of 'bud break'.

Chacko and Randhawa (1971) found that unlike many other tropical species, vegetative growth in mango was never continuous but exhibited periodical quiescence. The number of flushes varied greatly depending upon the variety, age of the tree, climatic conditions and the amount of crop borne in the previous season. They also reported that although flowering in mango trees generally took place during short days in the areas fall nearer to the equator, the very fact that off-season cropping was possible at Kanyakumari in South India suggested that flowering in mango is certainly under the environmental control, most probably photoperiod. They also reported that mango trees responded to temperature variations more critically than to photoperiods as evidenced by the different times of flowering at different places in India. The flowering is known to be earlier in areas nearer to the equator and late in North India, where extreme low temperature prevails during the winter months. In tropical conditions, pre-flowering rest period is usually achieved by drought at temperature above 15 degree Celsius (Whiley *et al.,* 1989).

Nunez-Elisea and Davenport (1992) reported that production of reproductive shoots requires initiation of growth during exposure to cool, inductive condition. The resting buds of plants, which had been exposed to cool temperatures (18 degree Celsius day/10 degree Celsius night) for more than three weeks and then transferred to a warm temperature regime (30 degree Celsius day/ 25 degree Celsius night) before initiation occurred, typically produce vegetative growth. The primary impact of water stress on mango is to prevent vegetative flushing during stress period. The accumulating age of stems is greater in water stressed trees than the trees maintained under well watered condition. (Schaffer *et al.,*1994). Flowering occurs in the subtropics when resting buds initiate growth during cool, inductive temperatures (Battern and Mcconchi 1995). Yeshtela *et al.,* (2004) found out that mango cultivar 'Keitt' was more sensitive towards low temperature floral induction than 'Tommy Atkins'. In the tropical highlands and sub-tropics, where most of the commercial orchards are situated, the low temperature during the winter months induced a severe growth check resulting in profuse flowering (Beal and Newman 1986). Rao (1998) reported that the minimum temperature of 13˚C for seven days favored FBD in mango cultivars 'Neelum' and 'Totapuri' under Dharwad conditions. Chen *et al.,*(1999) reported that the temperature is considered to be key environmental factor, with low temperatures (19 ˚C in day and 13 ˚C in night) favorable for fruit-bud-differentiation. Li *et al.,* (2010) recently reported that flower bud differentiation was delayed by high temperature and superabundant rainfall in subtropical monsoon climate zone and more easily affected by the overlap of current shoot growth.

3. Physiological factors associated with fruit-bud-differentiation

3a. Growth features and growth flushes

Different workers (Singh and khan (1940); Naik and Rao (1942); Sen (1943); Gandhi (1955) Burns and Prayag (1921) and Singh (1959) have reported different periods of occurrence of primary and extension growth depending upon the variety and the environmental conditions under which they worked. Singh and Khan (1940) reported that the shoots that flowered in the subsequent year made most of the growth early in the season and thereafter ceased growing about a month earlier as compared to the shoots that did not flower in the following spring. They also reported an antagonism between productivity and growth on the same shoots during the growing season, i.e. the potential for fruiting and vegetative growth were always at the expense of each other. Sen and Mallik (1941) observed the fruit-bud-differentiation at the end of September, although the shoots had ceased growing as early as June to July. They proposed that there was an interval between the time of cessation of growth and that of bud-differentiation. It was their belief that the shoots mature and accumulate appropriate reserves during this interval. Beal(1954) observed only or rarely two periods of active growth in dry zone of Sri Lanka as against two to six growth flushes in different mango cultivars in the wet zones, which he attributed to the irregular fruiting found in that zone. Nakaspone *et al.,* (1995) working under Hawaii conditions found that in 'Pairie' mango, the vegetative flushes were scattered throughout the year, the main flush period being summer months. An average of 18 moths was considered necessary by them between a vegetative flush and subsequent flowering. They also found that the terminals shoots were reactivated earlier than twelve months bonded to vegetative to rather than flower than those appearing earlier in the year.

Naik and Rao (1942) opined that mango flowers were borne mainly on the shoots that originated in the first flush of the previous year. They observed that early production of lateral shoots during the first flush followed by early cessation of growth and a period of dormancy preceding the flowering period appeared to be conductive for regular bearing in mango trees. Under western Indian conditions, Gandhi (1955) observed three main growth flushes namely, February to March, March to April and October to November, he, however, also speculated the possibility of the emergence of some of occasional flushes in between these main flushes. However, Teotia *et al.,*(1970) observed that under North Indian conditions, the main growth periods were March to July and February to November, respectively, with a peak occurring in June in case of 'Dashehari' and May in 'Langra'. The cultivar 'Nisarpasand' however, showed no such peak. They also observed flowering on shoots within a year flowering to the extent of 73 per cent in 'Nisarpasand, 88 per cent in 'Langra' and six per cent in 'Dashehari'. However, they also opined that stray shoots and sporadic extension growth might emerge at any time between July to October. Under South Indian conditions, two distinct active flushes, one occurring during February to June and the other during October to November were reported (Naik and Rao, 1942). They, however, noted significant differences in the magnitude of extension growth, duration of growing period, the time of peak growth and cessation of growth among cultivars in the same season.

Chowdhary and Rudra (1971) reported a direct relationship between the number of shoots growing in one season and in the subsequent spring. The fruit-bud-differentiation took place only in one-season-old shoots. They opined that the flushes that were initiated late in the season in respect of productivity in the following year. Thus, growth in mango took place in different flushes and varied in different parts of the country. According to most of the workers, early initiation and cessation of growth followed by a definite dormant period helped the shoots to attain proper physiological maturity, which is essential for fruit-bud-initiation. Most of the commercial cultivars of mango are prone to biennial bearing. Chacko and Randhawa (1971) noticed that the North Indian cultivars like 'Langra', 'Dashehari' and 'Chausa' grown under extreme humid tropical conditions flowered sparsely but did put forth profuse vegetative growth.

Most of the south Indian cultivars like 'Neelum', 'Bangalora' and 'Baneshan' on the other hand, produced fruis of inferior quality but could thrive well in both humid tropical and arid suibtropical conditions. The North Indian cultivars grown in South India showed, in general, pronounced apical dominance and grew upright as compared to the drooping habit of the shoots in the South Indian cultivars. Singh (1959) reported that the cultivar 'Baramasi' exhibited erratic and off-season bearing and others such as 'Totapuri Red Small', 'Neelum' and 'Bangalora' particularly the latter two showed distinct regularity. The off-season bearing in some of the south Indian varieties under Kanyakumri conditions appeared to be governed by the governed by the coastal climatic conditions. However, the behaviour of such cultivars was not consistent; by and large it was erratic. Even the regular bearing types if they carried a heavy load of crop in one year, showed a tendency towards reduced yield in the following year. Hence, he opined that the basic tendency of bienniality exists even in the so-called regular bearing types.

3b. Relationship between physical parameters of shoots and fruit-bud-differentiation

Galang and Lago (1935) stated that the mango shoots must have certain length, diameter and number of leaves for producing flowering. Singh (1959) opined that the mango shoots should attain a definite stage of maturity prior to the fruit-bud-differentiation. He observed that the shoots that differentiated buds were longer in length. In the cultivar 'Dashehari', on the contrary, he found that even though the shoots smaller and thin, measuring about one to three cm, differentiated fruit buds, which led him to deduce that there was no relationship between the length of the shoot and fruit-bud-differentiated shoot was significantly greater than that of the differentiated ones. However, in the cultivars 'Langra' and 'Dashehari' he could not establish any relationship between the girth of the shoot and fruit bud formation. After a comprehensive study of the various factors governing flower-bud-initiation in a number of regular and biennial bearing mango cultivars, Singh (1959) concluded that when the necessary stimulus is present, the fruit buds can differentiate and develop from any point of the tree irrespective of size and nature of shoots or sometimes even without new leaves, otherwise not.

3c. Role of leaves in fruit-bud-differentiation

According to Singh (1948), the number and the area of leaves, in particular, appeared to determine whether a spur differentiated a fruit bud or not. The necessity of adequate leaf area in the apple was explained to be largely to maintenance of sufficient carbohydrate reserves for fruit-bud-differentiation. Singh (1960) opined that there appeared to be no relationship between number of leaves and fruit-bud-differentiation in mango since he could observe even a tiny shoot with only one leaf developing a fruit bud. Singh (1971) demonstrated that the biennial bearing cultivars like 'Langra' and 'Dashehari' responded differently to defoliation than the regular bearing cultivars like 'Totapuri Red Small' and 'Baramasi'. It was observed that when defoliation was done in the 'off' year from October to December, the fruit-bud-differentiation ranged from 60.0 to 82.5 and 77.5 to 97.5 per cent respectively, in 'Langra' and 'Dashehari' but in 'Totapuri Red Small' and 'Romani' it was 100 percent. Singh (1971) demonstrated that through defoliation and ringing experiments, presence of leaves was necessary for fruit-bud-differentiation in mango. It was inferred that the flower inducing compound supplied by leaves was some hormone similar to the hypothetical florigen. Chacko and Randhawa (1971) also opined that absence of 'on' and 'off' year phases in regular bearing cultivars may be possibly due to the production of the flower inducing hormone even in young leaves.

Nunez-Elisea and Davenport (1992) reported that the floral inductive conditions are moderated by stem age; young resting stems bearing light green (or) recently matured leaves are more likely to produce vegetative shoots instead of reproductive shoots even if growth is initiated in floral inductive conditions. Nunez-Elisea and Davenport (1995) reported the minimum leaf age and time of exposure to a temperature regime (18˚C during day and 10˚C during night) required by stems to initiate inflorescence. Leaves become competent to responds to cool temperature when they reached seven weeks of age.

3.d. Effect of previous crop load on fruit-bud-differentiation

Thimmaraju (1966) in his investigation on some of the mango cultivars showed an interesting relationship between the total number of fruits harvested and the emergence of new shoots and their subsequent fruit-bud-differentiation. In 'Dashehari' it was observed that when the number of fruit harvested were optimum, less number of shoots were produced which in the following year failed to differentiate into fruit buds. In the 'off' year when there were no fruits, large number of shoots was produced which successfully differentiated into fruit buds.

4. Bio-chemical factors associated with flowering

4a. Role of carbohydrate and nitrogen reserves

As per the theory of Kraus and Kraybill (1918), high ratio of carbohydrates to nitrogen as major factor determining fruit-bud formation and fruit bearing played a dominating role for a longtime. The seasonal changes in the carbohydrate reserves and nitrogen content of mango shoots and their relationship with flower-bud-initiation were studied by Mallik (1953). In almost all the cultivars studied except in 'Baramasi', it was found that higher starch reserve, total carbohydrates and high C: N ratio in the shoots favoured flower initiation in mango. A study on the chemical constituents of shoots revealed that a higher starch reserve and total carbohydrates and C: N ratio at the critical time of fruit-bud-differentiation period appeared to favor flower-bud formation and amongst them greater accumulation of starch at the differentiation period seemed to be the most important factor for flower bud formation (Singh, 1960). Bakshi and Singh (1970) however, opined that a high level of carbohydrates and a high C: N ratio might accompany fruit-bud-differentiation, however they were not considered causal for the switch over of vegetative to floral axis.

Das Chowdhury (1969) attributed the favourable effect on flower initiation to appreciably increased concentration of all carbohydrates and the high C: N ratio caused by the girding treatment. Similar results were also reported by Malick (1953); Jyothi *et al.*, (2000) studied the biochemical changes in alternate bearing cultivars (Alphonso, Dashehari and Baneshan), regular bearing (Neelum and Totapuri) and hybrids (Mallika and Neeleshan). Under Karnataka conditions, changes in reducing, non-reducing, total sugars and starch were lower in regular bearers than alternate bearers during all the developmental stages. In regular bearing trees, reducing sugars were highest at FBD, hybrids registered lower sugars and starch contents than the alternate bearers where they declined during fruit development and later increased at maturity. Non-reducing and total sugar levels rise and fall pattern was noted from FBD to maturity. In alternate bearing trees, reducing, non-reducing and total sugars increased during FBD to flowering and then decreased from fruit development to maturity. The starch content in general declined from FBD to maturity.

Chacko (1968) reported that total nitrogen content was higher in the stem and leaves of trees, which were expected to initiate flower buds irrespective of the cultivar. However, no correlation was found between the content of total nitrogen or free 1-amino nitrogen in the stem and leaf and flower-bud-initiation of different mango cultivars. Similar results were obtained by Sen *et al.,* (1963). All the available evidences led Singh (1961) to opine that nitrogen and carbohydrate reserves played an important role in flower-bud-initiation though they did not form the primary cause and that the accumulation of these compounds might create a favourable condition for the synthesis and action of the substances that are actually responsible for flower induction in mango.

4b. Role of phenols

Patil *et al.,* (1992) estimated the total free phenols and polyphenol oxidase activity diurnally types of fruit bud of mango cultivar 'Alphonso', during fruit-bud-differentiation. Phenolic content of fruit buds increased steadily with advancing FBD, but remained stable in undifferentiated (or) scar buds. The activity of polyphenol oxidase was higher before and during FBD than afterwards.

4c. Role of mineral nutrients

Singh (1960) in his studies on biennial bearing of mango as related to chemical composition of shoots observed that the bearing shoots had higher nutrient status than the non-bearing ones in respect of CaO, MgO in 'Dashehari' and CaO, MgO, nitrogen and P2O5 in 'Langra'. It was found that except for K2O the nutrient status of 'Langra' shoots was found to be lower than of 'Dashehari'. 'Langra' shoots contained higher quantity of K2O, while 'Totapuri' and Baramasi did not show regular trends at all.

4d. Role of amino acids

Chacko (1968) found no qualitative differences in the composition of free amino acids and amides in the stem and leaves of different cultivars of mango during the different months of study. Chowdhary and Rudra (1971) on the contrary, reported that the concentration of all the free amino acids increased appreciably and the changes in the total free amino acids were largely due to changes occurring in the concentration of arginine and histidine at ripeness-to-flower stage.

5. Hormonal concept of flowering in mango

Sen (1943) suggested that there might be a special hormone and that a hetero-auxin might be discovered for practical use to induce flowering in mango. The terminal bud in mango was considered to inhibit the formation of axillary flower bud since the removal of terminal buds helped in producing inflorescence from axillary buds in the 'Haden' mango (Reece *et al.,* 1946). Further, it was also shown that floral primordial in the axillary buds were promoted by the presence of leaves and inhibited by the decapitated and ringed shoots could induce axillary flower buds but when the shoots were defoliated immediately or within twenty-four hours after decapitation, only vegetative shoots were produced by the axillary buds (Reece *et al.,* 1949). On the basis of these observations, Chandler (1950) proposed a hypothesis that flower induction in mango could occur only when the cell division had started and that a flower inducing hormone played no part in the initiation of growth; but when present in sufficient amount at the beginning of growth, it determined the course of differentiation of tissue in the axillary buds. He also proposed that if a hormone induced flowering in plants and the source of hormone was the leaf or some precursor formed in the leaf, then the leaf surface rather than the accumulation of carbohydrates might have the dominant influence on flowering. Sen (1951) opined that the problem of floral initiation in plants is not as simple as the one being controlled by the synthesis and accumulation of a substance up to a certain concentration but is a complex one involving a photo-mechanism controlling various growth and developmental processes.

Singh (1961) showed that the newly emerged leaves in the shoots of regular bearing cultivars such as 'Neelum' was capable of synthesizing flower inducing hormone. Chacko and Randhawa (1971) noticed a situation wherein three-month-old seedlings of 'Bangarlor' raised by stone grafting initiated flower buds, while in similar grafts of 'Langra' and 'Alphonso', the biennial bearing cultivars, only vegetative growth was produced. after two months, during December first week, flower bud emerged in case of 'Bangalora' grafts, whereas a second vegetative growth flush was observed in 'Bangalora' and 'Alphonso' grafts, demonstrating the inability of young leaves in biennial bearing cultivars to synthesize the flower inducing hormone. In the light of the above observation, it was proponed that the 'on' and 'off' year conditions in biennial bearing cultivars are governed by the synthesis (or non-synthesis) of a flower inducing stimulus which in turn depends upon the age and maturity conditions of the shoots. In regular bearing cultivars 'on' and 'off' year conditions do not exist possibly because of the production of the flower inducing hormone even in young leaves.

Singh (1959) demonstrated that the flower inducing stimulus could be transmitted from a mature tree of juvenile mango seedlings through grafting resulting the flowering of young stock, however, he found that the donating action shoots failed to induce flower in the non-defoliated seedling stock. He proposed that the high level of auxins produced in the leaves of the acceptor seedling counteracted the action of the flowering hormone donated by the action, resulting in lack of flowering. The response flowering in the receptor seedling was the same irrespective of cultivar involved, indicating that the nature and action of flower inducing hormone was the same in both regular and biennial cultivars.

5a. Role of auxins

Chacko (1968) found a high level of auxin-like substance in the shoots of 'Dashehari', which were expected to flower. The work of the same person on the naturally occurring growth substance in the shoots of 'Dashehari' and 'Totapuri Red Small' indicated the presence of a zone on paper chromatograms containing growth promoting substances, which exhibited biological properties similar to auxins. The shoots from 'Dashehari' 'on' year and 'Totapuri Red Small' trees, which initiated flower buds during the experimental period had a higher level of growth promoting substances during the period of flower-bud-initiation than the shoots of 'Dashehari' 'off' trees which remained vegetative. Daschowdhary (1969) observed that in the neutral fraction of 'Langra' shoot extract, a growth promoting substance occurred at Rf 0.7 to 0.8 on paper chromatogram developed in isopropanol : ammonia : water. It was found that the highest concentration of the promoter coincided with the ripeness to flower stage.

5b. Role of gibberellin-like substance

In many of the cold-requiring biennials and long-day annual plants, Gibberellins are known to be involved in the production of floral stimulus. A study of Chacko (1968) showed that the amount of gibberellin-like substance was higher in the shoot extracts of 'Dashehari' 'off' season trees as compared with those of 'on' trees, which were differentiating fruit of grafted seedling as reported by Singh (1959) was interpreted by Singh (1971) as owing to its high content of endogenous gibberellins.

5c. Role of inhibitors

Chacko (1968) reported the presence of certain inhibitors similar to abscisic acid in mango shoots. His findings that the shoots of 'Dashehari' during 'on' year and 'Totapuri red Small' trees had relatively higher levels of this inhibitors during flower-bud-initiation than the shoots of 'Dashehari' in 'off' trees, indicated that the inhibitors might be involved in the initiation of flowering in mango. Daschowdhury (1969) observed a correlation between inhibitor (abscisic acid) level and growth of 'Langra' twigs. The maximum activity of the inhibitor in the shoots of 'Langra' coincided with the period of growth cessation and its activity was least when growth took place. Further, The observation that defoliation of ringed shoots of 'Dashehari' and 'Janardhan Pasand' 'on' trees activates vegetative buds in such shoots, suggested that the inhibitor produced in the leaves is necessary for checking vegetative growth (Singh, 1971). Thus, the exact role of inhibitors in the initiation of flower buds in mango is not fully understood. Since the inhibitor is antagonistic to both gibberellins and auxin thereby affecting cell elongation. Singh (1971) speculated that the inhibitor might help in checking vegetative growth of mango thereby providing conditions suitable for flower-bud-initiation. Chowdhary and Rudra (1971) also observed an inverse relationship between the level of the inhibitors in shoot and vegetative growth and consequently a position association between inhibitors level and flowering of 'Langra' trees. They also reported a significant rise in the level of inhibitors with the application of Cycocel, which caused early and complete cessation of shoot growth and significantly promoted the flowering of 'Langra' mango trees. Jogdande and Chowdhary (2001) conducted a study employing three mango varieties to find out the seasonal changes in abscisic acid level in the shoots. They found that all the cultivars ranged from Rf 0.9 to 1.0. Cultivar 'Neelum' showed the highest activity in all the stages of shoot development. 'Alphonso' ('on' year) which did not flower in the following season showed the lowest total abscisic acid-like substance content. The abscisic acid content in all the cultivars increased as the time progressed; while on the other hand, the increase was marginal in 'Alphonso' ('on' year) and highest in 'Neelum' followed by 'Pairy' and 'Alphonso' ('off' year). The results showed that there were certain inhibitors similar to abscisic acid, which were relatively higher in the shoots of mango tree during flower-bud-differentiation.

Conclusion

Fruit bud differentiation denotes the partitioning of metabolites from source to sink and this process is influenced by crop load, bearing habit, genetic character, age and size of shoot and other plant factors. In addition to the above factors, climatic factors such as temperature, water stress, and photoperiod also influence fruit bud differentiation. The fruit-bud-differentiation starts from 5 to 6 months before the actual flowering for which in one season old shoots differentiates. Different workers have reported different timing or period of fruit differentiation under Indian conditions and also in other places. The knowledge of the time of fruit-bud-differentiation under a particular set of climatic conditions for a given variety would enable the orchardists to schedule the manuring, irrigation and other cultural operations to have better yield

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