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Induction of off-season flowering in mango through farmer's participatory research in Krishnagiri district under NAIP

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Abstract
Down south India, mango starts flowering from December- January and yields from April to July. During on years, there will be a huge arrival of mangoes from June to July leading to glut, resulting in slashed price, leaving farmers with very low profit. The long felt need of the farmers of Tamil Nadu is to produce mangoes out of season to fetch a rewarding profit. Several attempts were made to identify mango varieties yielding off season and the ways to obtain off season fruits. There are reports about varieties yielding off season fruits but not consistently. However, induction of flowers either through canopy management or through chemicals will be more reliable than the varieties. Off season production in mango could be achieved by imposing a set of treatments on varieties responding to chemicals. The treatment induced the trees to flower during July - August so that fruits could be harvested during December – January. The off-season production of mango is highly economical advantageous as getting a premium price in the market is ensured. Identification of traditional and non - traditional mango growing belts suitable for off-season production and popularising the technology would extend the period of availability of fruits for domestic and export markets besides improving the livelihood and status of the mango growers.

Keywords: Mango - off-season flowering - induction - chemicals - canopy management

Introduction
The Mango (*Mangifera indica* L.), member of family Anacardiaceae, is amongst the most important tropical fruit of the world. Indo – Burma-Siam regions and Philippines are considered to be the probable places of origin of mango. Besides delicious taste and excellent flavour, mango is rich in vitamins and minerals. Mango has been under cultivation for more than 4000 years in India. India continues to be the largest mango producing country of the world, accounting for more than 50 per cent of the world production. Flowering is the first of several events that set the stage for mango production each year. Given favorable growth conditions, the timing and intensity of flowering greatly determines when and how much fruits would be produced during a given season. Insight into this phenomenon has been of prime interest to scientists and growers for over a century.

Flowering behaviour of mango
Flower initiation is very important because it is the first step towards attaining fruit and it is very complex phenomena in mango. Flowering in mango trees make them especially challenging for physiologists, breeders, and growers; Mango is a terminal bearing species and the factors which determine switching from vegetative to reproductive mode are poorly understood. In general first, mango pass through a juvenile stage which lasts for several years following germination during which flowering does not occur; second, interactions between vegetative growth, flowers, and fruit of the previous year on floral initiation in the current year, affect growers through phenomena such as biennial bearing, and make interpretation of research data difficult for scientists.

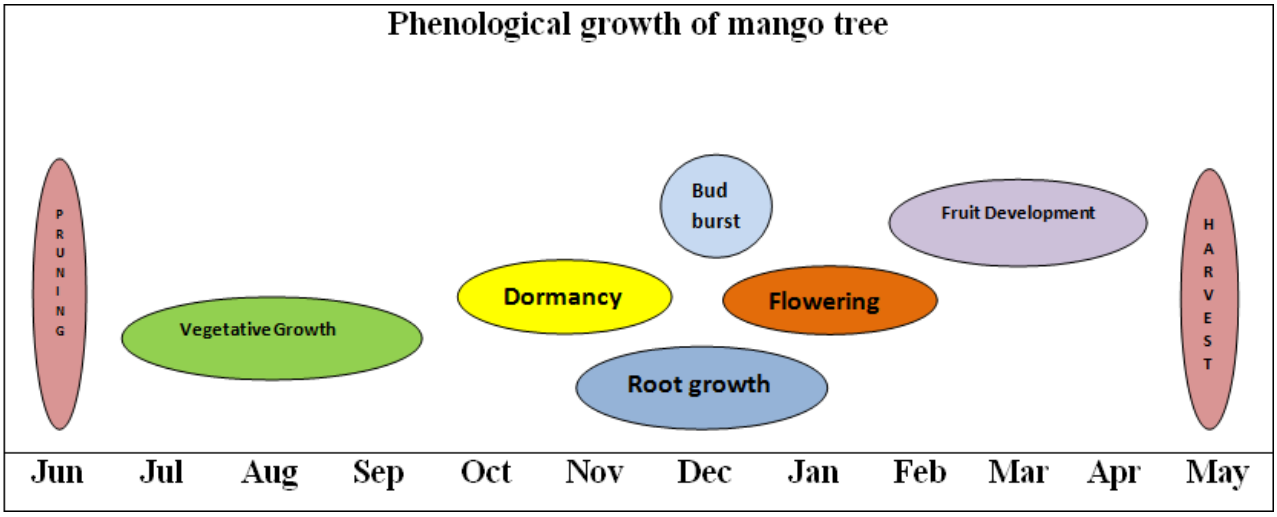
Once flowering capacity is attained, mango tree respond to environment cues such as light (especially relative lengths of light and dark periods), temperature and nutrition. In mango flowering has been found to be chemically controlled. Leaves are the sites of control substance synthesis; apices are receptor sites. It has been suggested that this control may takes the form of: (a) a single flowering factor (Florigen), (b) a group of flower promoting substances, (c) one or more flower inhibiting substances, or (d) interaction between flowering promoters and inhibitors and vegetative growth cycle.

South Indian scenario of mango flowering

In South India, mango generally starts flowering from December- January and yields from April to July during normal rainfall years. If rainfall is excess, fruiting would be shifted accordingly by a month or two. During on years, there will be a huge arrival of mangoes from June to July leading to glut, resulting in slashed price, leaving farmers with very low profit. The long felt need of the farmers of Tamil Nadu is to produce mangoes in off-season in order to fetch a rewarding profit. Several attempts were made to identify mango varieties yielding off-season and the ways to induce off-season fruits. There are reports about varieties yielding off-season fruits but not consistently. Therefore, most of the mango workers feel that the induction of flowers either through canopy management or through chemicals would be more reliable than selection of off-season varieties.

Phenological growth of mango tree

Before adopting any technologies, it is important to understand the phenological growth of the tree so that the cultural operations can be taken up at right time to get right results. Phenological growth of mango trees of South India is depicted in the diagram.



It clearly shows the different growth stages so that, canopy management can be taken up at an appropriate time for the desired results. Mango produces flowers from December onwards under normal circumstances and the flowering can extend up to March. However, the fruit development phase range from January to May depending upon the time of flower formation. Harvest starts from April continue up to June and at times extended up to August. For early varieties, harvest is over by May and the tree is ready for pruning by June. After harvest, mango trees put forth vegetative growth till September. Fruit bud initiation and differentiation takes place during October-November and then the buds enter into dormancy. Root growth takes place during November to January. Bud burst takes place any time between November and December depending upon the environmental factors like night temperature dry weather before flowering.

Flowering VIS-À-VIS yield

Gaining knowledge on floral biology of mango is very important because sex ratio has a direct correlation with the production. Growers need to use flowering treatments, but achieving high levels of flowering alone is not a guarantee for achieving high yield. It is likely that aspects of management between flowering and harvest are critical to achieving high rates of conversion of flowers to fruit.

Mango inflorescence is primarily terminal but axillary and multiple panicles may also arise from axillary buds quite frequently. The panicle consists of a main axis bearing many branched secondary axes. The secondary branches may bear a cyme of 3 flowers, or tertiary branches may again arise on them which bear a cyme of 3 flowers, each flower borne on bracteate pedicel. The flowers are closely clustered towards the apices of each branch or main axis and are either male or hermaphrodite. The total number of flowers in a panicle may vary from 1,000 to 6,000, depending upon the variety. The panicle of the mango also varies in length from a few centimetres to 60 cm. It is the hermaphrodite flowers that after proper pollination and fertilization set fruit. Therefore the initial fruit set will depend much on the number of hermaphrodite flowers in a panicle. The percentage of hermaphrodite flowers in a panicle is subject to appreciable variation, depending upon the early or late emergence of the panicle and the variety.

Under north Indian conditions percentage of perfect flowers in the panicles of 'Dashehari' and'Langra' is 30.6 and 69.8 respectively. In the south Indian mangoes it varies from 16.41 in 'Neelum' to 3.17 in 'Allampur Beneshan'. The percentage of perfect flowers varies from 2 to 70 according to the variety. The percentage of perfect flowers in the panicles of medium and late flushes in 'Dashehari' was respectively 2 and 7 times more than that in the panicles of early flush. Panicles in the inner portion of the tree bore 1.5-2 times more perfect flowers than those located on the periphery. The number of hermaphrodite flowers is the least in the upper pan of the panicle but the percentage is the highest. Fruit set and ultimate retention per panicle are much higher in the medium and late emerged panicles than in the early ones. There appears to be a close association between high temperature and an increased percentage of perfect flowers, and low temperature and a decreased percentage of perfect flowers. The percentage of perfect flowers in some of the south Indian varieties has been observed to be much less under north lndian conditions. This has been attributed to the lower maximum and minimum temperatures obtaining during the period of panicle development at Delhi compared with those obtaining at Kodur (:south India).

The percentage of perfect flowers in 'Janardhan Pasand' and 'Beneshan' is significantly increased with the aid of NAA (200 ppm) sprays. The increase in the percentage of perfect flowers by NAA sprays results in much higher fruit set per panicle in

'Beneshan', which is shy when grown under north Indian conditions. Mango is a cross-pollinated crop and pollination is essential for fruit set. It 'is primarily accomplished by insects; housefly (Musca domestica L.) being the chief agent Pollen production in 'Dashehari', Langra' and 'Chausa' is significantly higher in the late flush than in the early flush (Sharma and Singh 1970). It may be as high as 2,025 per anther in the late flush of panicles. Pollen viability in mango is quite high (93%). Pollen germination on the stigma is quite normal. The stigma remains receptive even up to 5 days after anthesis. Environmental factors, however, influence the receptivity of stigma appreciably. For a better fruit set, need for adequate and efficient transfer of pollen has been emphasized by many workers. However, unpollinated flowers of Dashehari' can continue on the panicles up to 13th day after anthesis. At this stage the mean size of the ovary and the ovule may be about 2.5 times than at anthesis. Therefore the initial fruit set should be recorded at 'marble' stage to have an accurate estimate.

Fruit set is a varietal character, depending upon several factors such as time of flowering, sex ratio, efficient cross-pollination and intensity of flower drop. Varieties differ from one another in these respects and this leads to varying fruit set in different varieties. Under Delhi conditions the panicles of the early flush of Dashehari' emerge rather early in the season and at 'that time the majority of the varieties are not found in flowering. The weather is also much cooler at that time and the pollen transference is also less. Consequently, the mean fruit set is negligible in the early flush of Dashehari'. The panicles of the late flush of Dashehari', on the contrary, show high fruit set and ultimate retention per panicle. Fruit drop an mango there is a heavy drop of hermaphrodite flowers and young fruits, amounting to 99% or more.

Among the external factors affecting mango fruit drop in the initial stages, mention may be made of mango hopper, mango mealy bug, powdery mildew and anthracnose. Deficient nutrition of many developing embryos may be the most important internal factor leading to post-fertilization drop in mango. This results due to competition among over-crowded fruitlets on a panicle. Degeneration of the embryo in the initial stages of its development may yet be another cause of drop. This occurs invariably if the flowers are self- pollinated. So far no control measures have been evolved to check the fruit drop in mango. Except in some varieties such as 'Langra' and 'Chausa', natural fruit drop does hardly pose a problem in normal bearing. However, drop due to insect and disease attack must be checked in all the varieties by applying appropriate insecticides and fungicides. Cross- pollination of the varieties ought to be assured by avoiding isolated planting of a single variety. Check of natural fruit drop in mango will result in the intensification of alternate bearing habit.

Flower Regulation Through Various Interventions

1. Canopy Management

Though many reasons are attributed for low productivity, poor canopy management is considered as one of the major limiting factors in mango production. Being an evergreen tree, mango is seldom pruned in India, which leads to over-crowding of branches resulting in poor penetration of sunlight causing low productivity coupled with inferior quality fruits. Regular training and pruning operations are very much essential to have a productive canopy. The extent of pruning has an impact on the flowering and fruiting. Mango trees under ultra high density planting system have to be pruned every year to avoid interlocking. Severe pruning *i.e.*, total removal of past seasons' growth resulted in poor flowering (Gopu *et al.*, 2013) [11].

Davenport (2007) [9] reported that shoot initiation is stimulated by pruning, defoliation, irrigation during dry conditions, application of nitrogen fertilizer, and other factors, *e.g.*, exposure to ethylene or a shift from cool to warm temperatures. Frequent flush events occur in young trees and in mature trees in conditions of high nitrogen and abundance of water. Other factors that stimulate initiation of shoot development include stem pruning, defoliation, foliar nitrogen sprays and ethylene. Induction, controlling the type of shoots that are evoked upon initiation, appears to be governed by the interaction of a putative temperature-regulated florigenic promoter (FP) and an age-dependent vegetative promoter (VP) (Davenport and Núñez-Eliséa, 1997; Davenport, 2003, 2008) [6, 5, 8].

Flower induction through nitrogen manipulation

High nitrogen levels, especially under well-watered conditions, are conducive to initiation of frequent vegetative flushes. Nitrogenous fertilizers should never be applied nearer to the time of pruning which would induce second flushes before the stems have achieved sufficient maturity. Reduction of vegetative flushes can be accomplished by limiting nitrogen fertilizer application to trees until the desired flowering time. It is critical to maintain the annual leaf nitrogen levels sufficiently low to discourage unwanted vegetative growth during the period approaching the desired flowering date. Davenport (2003 & 2006) [8] correlated high leaf nitrogen levels with frequent vegetative flushes in mango. Hence, it is advisable that leaf analyses for nitrogen levels should be conducted on the last flush of leaves at least once or preferably, twice a year. If one analysis is conducted, it should be done just prior to the synchronizing prune. An observation of Davenport (2007) [9] says that the leaf nitrogen levels for mango should be 1.1 to 1.4 per cent at the time of synchronizing prune event in order to avoid possible second flushes.

2. Chemicals

Potassium Nitrate Spray

KNO3 can enhance flowering especially in tropical regions where cold temperature for floral induction may not be sufficient. That is due to its reported effect in supplementing nitrogen. It is also suggested that induction by potassium nitrate spray occur as a result of ethylene synthesis. The overall effect of potassium nitrate when sprayed at different periods of phonological phases, concentration and locations as well as the mechanism for its effect is reviewed here.

Potassium nitrate (KNO3) came into general use in the Philippines in the 1970s. It too was speculated to stimulate flowering through a wound-ethylene response. It now is widely used in Mexico as well. Although responses may occur at concentrations ranging from 1 to 8 percent, Mexican growers generally use 4 percent KNO3 or 2 percent ammonium nitrate. Bondad and Linsangan (1979) reported that concentrations of potassium nitrate between 1 and 8 percent stimulated flowering of seedling 'Carabao' and 'Pahutan' trees and 'Pico' trees within one week after sprays were applied. The treatment was effective for stimulating flowering of trees that had remained vegetative well beyond normal bearing ages, for advancing the flowering and fruiting periods, and for breaking the biennial bearing habits of trees. Potassium nitrate is currently recommended in the Philippines for inducing uniform flowering and for the production of off-

season fruits in the 'Pico' and 'Carabao' cultivars (Madamba 1978). In India, workers have reported variable results with potassium nitrate (Pal *et. al.* 1979). Areas that have reported success with potassium nitrate include Trinidad with 'Tommy Atkins' (James *et al*. 1992), the Ivory Coast with 'Kent' and 'Zill' (Goguey 1992) and Mexico with 'Manila' and 'Haden' (Nunez-Elisea 1985; 1986).

Work in Mexico showed that mango flowering could also be stimulated with ammonium nitrate sprays (Macias-Gonzales *et al*. 1992; Nunez-Elisea 1988, Nunez-Elisea and Caldeira 1992). Concentrations of 2 percent ammonium nitrate were sufficient to promote early flowering in 'Haden', 'Tommy Atkins', 'Kent', 'Diplomatico' and 'Manila'. The similar results between ammonium and potassium nitrate indicate that the nitrate ion is the active portion of the molecule.

Experiments in Hawaii by Mike and Melvin (1990) showed that 2 and 4 percent potassium nitrate sprays applied to mature seedling trees early in the flowering season (February,1986) stimulated flowering. A single application stimulated flowering within three weeks after treatment, and maximum response was observed at about four weeks. Off-season flowering was also stimulated when application was made to seedling trees in May after the flowering season was completed. Nearly 16 percent of the terminals treated with 4 percent potassium nitrate flowered by six weeks after treatment. Their results also showed that terminals that flowered were associated with specific trees; some trees in the test exhibited no response, while others produced vegetative terminals after treatment. These results suggest that potassium nitrate did not induce flowering, but probably stimulated growth of terminal buds. Flowering was determined by the condition of the terminal bud or the environmental conditions at the time potassium nitrate application was made. Their results with seedling trees also showed that genotypic differences among trees exist with regard to flowering responses to potassium nitrate. Some trees were highly responsive to the treatment and flowered, while others produced vegetative shoots instead of panicles.

Mosqueda (1989) reported that KNO3 was effective in stimulating the emergence of mango inflorescences more than 30 days in advance in Manila mango. Foliar application of KNO3 stimulated flowering of mango (Yeshitela *et al*., 2004) [18]. It is possible that KNO3 increased cell division and enlargement in the meristematic zone (Protacio, 2000).

3. Smudging

Smudging is making the Smoky fire below the tree canopy and allows smoke to pass through the foliage for several days. To produce heavy smoke, place green grasses on top of combustible materials such as dry leaves and coconut husks. Smudging is an early commercial method of inducing mango to flower (Wester, 1920). Gonzales (1923) and Borja and Bautista (1932) considered only mature shoots of 1 year or older with very brittle, dull greyish green to copper coloured leaves and plump terminal buds are suitable for smudging.

Smudging of the mango is practiced in certain parts of the Philippines to obtain earlier and increased flowering of 'Carabao' and 'Pico' mango (Dutcher 1972; Gonzales 1923; Madamba 1978) [10]. Ethylene has been identified as the active agent responseble for flowering during smudging (Dutcher 1972) [10]. Smudging is done continuously for several days and is stopped if flower buds do not appear within two weeks. The process may be repeated 1-2 months later, but results are uncertain. It is not, however, known to be practised in India or in any other mango tract, or even much widely in the Philippines.

According to Sen and Mallik (1947) Experiments were conducted at the Fruit Research Station, Bihar, and Sabour India with the Langra Mango in order to study the effect of smudging treatment on the plant under the local conditions. Instead of flowering smudging has stimulated vegetative growth. In addition to normal shoots arising from terminals large number of axillary buds appeared in clusters to form malformed bunchy growths. It is apparent that smudging has a stimulating effect on growth, but the nature of growth, reproductive or vegetative, depends on other factors. One of the previous workers also concludes that smudging can induce flowering only if the shoot is in condition to flower. But none of them mention any effect of stimulating excessive vegetative growth as shown in these experiments. Opinion differs as to whether the smudging is due to heat of the smudge or due to smoke. It is not considered to be due to the heat as the average difference of temperature between the treatment and the control was only 2°C. According to them Ethylene gas which is one of the chief constituents of the smudge smoke, produced by burning vegetative matter, are known to have given similar effect on pineapple. It is, therefore, thought that stimulating effect of smudging is due to the smoke. So they declared that it is intended to continue the study in connection with researches on the physiology of the mango.

4. Growth Inhibitors

Earlier works on floral manipulation in mango plants, revealed that floral initiation in trees is controlled by a range of factors which includes environmental stimuli, developmental cues and other interactions with vegetative growth and PGRs and it is also apparent that rarely one factor can be considered in isolation. In above circumstances, growth retarding chemicals, e.g. triazoles group (paclobutrazol, PBZ), that can stimulate or mimic the effects of the environmental factors in checking vegetative growth are sometimes used to correct such a situation (Nartvaranant *et al*., 2000) [12] as reviewed above. Paclobutrazol sold in the tropics under the trade name Cultar (Syngenta Corp., also available from several Chinese manufacturers and distributors), reduces the period of dormancy which is necessary to allow floral induction during warm temperature conditions by approximately one month (Davenport, 2003) [8], thus increases the potential to produce reproductive shoots in younger stems upon shoot initiation.

Application of paclobutrazol or uniconazole [Sumitomo Chemical Co. (international) or Valent Corp. (USA)], triazole compounds that inhibit synthesis of kaurene oxidase in the gibberellin-synthesis pathway (Dalziel and Lawrence, 1984; Rademacher, 1991) [4, 13], stimulates the production of flowering shoots during these weakly inductive conditions (Burondkar and Gunjate, 1993; Tongumpai *et al*., 1991; Voon *et al*., 1991; Nartvaranant *et al*., 2000; Yeshitela *et al*., 2004) [1, 16, 17, 12, 18]. Thus, field application of paclobutrazol to trees bearing one-month-old mango shoots produced inflorescences from those stems when bud break was initiated three months later by a foliar application of KNO3 (Davenport, 2003) [8]. The triazole plant growth retardants, paclobutrazol (Cultar, Zeneca Corp.) and uniconazole (Sumitomo or Valent Corp.) inhibit gibberellin biosynthesis (Rademacher, 1991) [13] and therefore, reduce the levels of the putative vegetative promoter which is thought to be a gibberellin. Both products are effective for assisting in floral induction with uniconazole

being more effective than paclobutrazol. The triazole products provide the flexibility needed to shift the flowering time of the more-difficult-to-manage cultivars like 'Tommy Atkins' to any week of the year with less concern for early vegetative flushes. For this reason, Cultar has been widely marketed throughout the tropics to stimulate mango flowering. Either product should be applied after the onset of re-growth following pruning (1-1.5 months after prune date) depending upon cultivar.

Paclobutrazol should be applied as a soil drench containing 1 to 1.5 grams of active ingredient per meter of canopy diameter (Nartvaranant *et al*., 2000) [12] if applied during the rainy season, but personal experience has shown that about half that amount is needed if applied during the dry season. It takes at least 90 days for either product to exert an effect in trees (Nartvaranant *et al*., 2000) [12]. Earlier initiation of flushes results in formation of vegetative shoots so it is important to avoid growing conditions that promote the initiation of frequent flushes when paclobutrazol is applied.

Methodology

The experimental site Pochampalli taluk is geographically located at 12° 20' N latitude, 78° 22' E longitude at an altitude of 300 m above mean sea level. The annual average rainfall was 830mm. The soil in the experimental field was dark reddish brown, sandy loam. Induction of off-season flowering in mango in the project site was taken up as farmers' participatory research. The farmers growing mango cv. Bangalora were selected to take up the research trials in their field. A group of 25 farmers from Gurugapatti, Pochampalli, Krishnagiri district registered under the NAIP scheme on "A value chain on mango and guava for domestic and export markets" participated in the research programme for off-season mango production in order to fetch a premium price. The regular flowering season (December-January) was skipped by encouraging vegetative shoots in the season. Leaf analysis was done during August in order to find the nitrogen content and also to decide the amount of nitrogen to be applied to induce vegetative growth. Trees having > 2.5 per cent leaf nitrogen content were applied with the normal dose of fertilizers, between 1.4 to 2.4 per cent were applied with 200 per cent and <1.4 per cent were applied with 250 per cent. Besides the trees were also irrigated copiously to induce as many vegetative shoots as possible. Less than 10 per cent flowering was observed in T1 and 10-15 per cent in T2 and T3. Panicles in all the treatments were stripped off periodically till March and stray flowering was noticed even after stripping. During the month of March, centre opening and pinching of shoot tip was done. Followed by centre opening, the trees were applied with the correct dose of paclobutrazol *i.e.*, 1.0-1.5g of active ingredients per sq.m based on the size and age of the mango trees. The treated trees started producing panicles from 90 days after the application of paclobutrazol and continued upto 120 days. Generally, flowering was observed in the first week of July in all the treatments and extended upto August.

Table 1: Leaf nutrient content in mango cv. Bangalora (15-25 years old) August

Treatment	Leaf nitrogen content (%)	No. of farmers	Fertilizer applied
T1	>2.5	12	Adopted recommended dose of N, P & K (1:1:1 kg/tree/year)
T2	1.4-2.4	8	Adopted 200% recommended N along with recommended dose of P & K (2:1:1 kg/tree/year)
T3	< 1.4	5	Adopted 250% recommended N along with recommended dose of P & K (2.5:1:1 kg

Table 2: Flowering percentage and yield observed in mango cv. Bangalora (15-25 years old)

Treatment	Leaf nitrogen Content (%)	Flowering percentage during June-July	Calculated Yield ha^{-1} (t) (Oct.-Dec.)
T1	>2.5	70	14
T2	1.4-2.4	83	17
T3	< 1.4	89	20

The flowering percentage varied from 70 to 89 per cent (Table 2). Harvesting started in the last week of October and continued for two months. On an average, one hectare has 200-250 mango trees. The individual tree yield varied from 80 to 100kg/tree. The calendar of operations for mango cv. Bangalora practiced in the farmers field for the year 2012 and 2013 are as given below.

Table 3: Calendar of operations for mango cv. Bangalora during First Year (2012)

1	2	3	4	5	6	7	8	9	10	11	12
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering ↑				Harvest ↑			↑ Leaf Nutrient analysis excess N2 application		↑ 2-3 vegetative flushes		

Table 4: Calendar of operations for mango cv. Bangalora during Second Year (2013)

1	2	3	4	5	6	7	8	9	10	11	12
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vegetative growth ↑		Pruning ↑	PBZ ↑			Flowering ↑				Harvest ↑	

PBZ- Paclobutrazol application

Future thrust areas

It is apparent that floral initiation in trees is controlled by a range of factors which may include environmental stimuli, developmental cues, and other interactions with vegetative growth and PGRs. It is also apparent that rarely can one factor be considered in isolation. Research in trees is expensive, slow, and has often been focused on limits to production in perennial trees like mango. So after thorough assessment of different methods or practices application / use of particular practice can be recommended. Research efforts should be strengthened on flowering physiology especially in genetic control of flowering in mango.

Conclusion

Off-season fruits are suitable for both table purpose and pickle making. However, the success in producing off-season mango is also dependent on other factors such as climatic conditions, mango cultivars, orchard management and most importantly the experience of mango growers. Armed with the basic information provided here, growers could manage flowering at any desired week of the year. The flowering program can be started at any time regardless of the presence or absence of fruit. Other factors, however, such as harvest of the previous season's crop, timing of the dry and wet seasons and high susceptibility to disease during rainy seasons are important considerations which deciding on the starting of the flowering program. Local environmental conditions may alter the expected responses, but scrutiny of all the factors will bring consistent success.

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