International Journal of Chemical Studies

Floral induction in mango: Physiological, biochemical and molecular basis

Dhiru Kumar Tiwari, VB Patel and AK Pandey

Dhiru Kumar Tiwari
Department of Horticulture
(Fruit and Fruit Technology),
Bihar Agricultural University,
Sabour, Bhagalpur, Bihar, India

VB Patel
Department of Horticulture
(Fruit and Fruit Technology),
Bihar Agricultural University,
Sabour, Bhagalpur, Bihar, India

AK Pandey
Department of Fruit Science,
ACHF, Navsari Agricultural
University, Navsari, Gujarat,
India

Abstract
Mango (*Mangifera indica* L.) is one of the oldest and most important fruit tree grown in many tropical and subtropical regions. Flowering is the first of several events that set the stage for mango production each year. It also influences the quality and quantity of fruits. Floral induction processin mango occurs before the onset of the coolest months of the year. Temperature, florigenic promoter, inhibitors, auxin, cytokinin, gibberellin, carbohydrates, amino acids, phenols, enzymes and genetic factors play important role in the floral induction of mango. Mango flowering involves hormonal regulation of shoot initiation and induction events resulting in reproductive shoot formation. A prospective may be made, if the Arabidopsis genes (*Constans* and floral signaling gene, *FT*) are inserted and expressed in mango in order to explain the requirement for such a small amount of signal to induce flowering. This advancement may be milestone in the floral induction of mango.

Keywords: Floral induction, mango, Physiological, biochemical, molecular

Introduction
Mango (*Mangifera indica* L.) is one of the oldest and important fruit crop grown in tropical and sub-tropical regions of the world. It belongs to the family Anacardiaceae. Mango is known as 'King of Fruits' due to its superb, juicy, tasty and very colorful fruit (Singh, 1996; Krishna and Singh, 2007) [54, 88]. Mango is a perennial evergreen tree but it has problematic tendency of alternate bearing and this tendency is due to erratic flowering. Mango occupies the third place in the world production of major tropical fruit crops (Alonso and Blaikie, 2003) [5] while banana and citrus fruits are first and second place respectively. Because of its excellent flavour, attractive fragrance, beautiful shades of colour, delicious taste and high nutritive value mango is now recognized as one of the best fruits among all the indigenous fruits of India (Ibrahim *et al*., 1999) [49]. India is the leading producer of mango in world accounting more than 50% of total production worldwide. Currently, mango is cultivated in an area of 2.29 million hectares with a total production of 15.18 million tonnes in India. The average productivity of 6.6 metric tonnes per hectare in India is comparatively low against 35-40 metric tonnes per hectare realized in Israel (NHB, 2011). Besides India other mango producing countries are Mexico, Pakistan, Brazil, Philippines and Thailand. The composition of mango generally differs with cultivars and the stage of maturity. Mango is rich source of Vitamin A (4800 I.U.). It also contains 0.1 per cent fat, 8.8 per cent carbohydrate and other nutrients in less quantity. Mango is a prized summer fruit crop of India with over one thousand recognized varieties consumed as fresh fruit or variously processed products. Different processed products are prepared from mango such as squashes, nectar, jam, leather, pickles and *amchoor*etc.

Floral induction also play vital role in the succession of commercial orchards particularly of cultivated mango crops (Buban and Faust, 1982; Forshey and Elving, 1989) [13, 44]. It influences the quality and quantity of fruits (Link, 2000) [57]. Mango flowering is an important physiological event that sets the initiation of fruit production. Initiation is the first event that takes place for mangoes to flower (Davenport, 2009) [38]. Mango flowering process occurs before the onset of the coolest months of the year. Flowering requires 4–6 weeks of shoot dormancy and cool night temperatures to trigger floral induction of the terminal buds. Mango trees flower in response to the age of the last vegetative flush in tropical and subtropical conditions. Complex interactions between shoot developmental stage and environmental conditions resulted in the floral initiation in mango. Phenological and physiological models of vegetative growth and flowering in mango have been proposed by a number of workers (Cull, 1987; Chacko, 1991; Kulkarni, 1991; Davenport, 1993) [29, 55, 17, 37] application of nitrogen

Correspondence
Dhiru Kumar Tiwari
Department of Horticulture
(Fruit and Fruit Technology),
Bihar Agricultural University,
Sabour, Bhagalpur, Bihar, India

substances and/or fertilizers and exposure to ethylene can also stimulate the floral initiation (Davenport, 2009) [38]. Formation of terminal intercalary units of branches after the extension and lateral growth of mango stems occurs in periodic flushes of elongating shoots. For the survival of angiosperms flowering is the single most important event. Many different mechanisms are involved in woody tree species in this phylum (angiosperm) to ensure the success of this event (flowering). In northern hemisphere flower induced during October-December in mangoes and in the Southern hemisphere during June-August. Alternate bearing is the chief problem in mango which varied in the time and intensity of flowering from location to location and year to year to almost complete biennial (alternate) flowering habit, is not an uncommon phenomenon (Abdel Rahim et al., 2011) [1]. Flowering is very difficult to understand in case of mango because of its different floral initiation time and behaviour at different locations. It is important to understand floral induction in trees of mango to ensure regular flower bud formation, which is a prerequisite for stable production every year. Many research works have been conducted on flowering in relation to environmental factors, cultural conditions, or plant growth regulators, and regulation of the floral induction has been discussed. In Mango flowering, initiation is the first event that takes place for flowering and that is an important physiological event that sets the start of fruit production. Given favorable growth conditions, the timing and intensity of flowering greatly determines when and how much fruit are produced during a given season. Mango flowering involves hormonal regulation of shoot initiation and induction events resulting in reproductive shoot Formation (Davenport, 2007) [33]. Limited knowledge of the biochemical and molecular mechanisms which control the flowering (an essential precursor to mango production) are the potential for increased productivity is constrained (de los Santos-Villalobos et al., 2011) [42]. As a consequence of efforts to elucidate the mechanisms of this critical biological event in mango and other model plant systems, many of the important details are becoming clearer at the molecular, biochemical, and physiological levels resulting in a better understanding of how to manage flowering in the field. Further research works is needed for the better understanding about the mechanism of floral induction of this major and most important fruit crop.

Floral Initiation and Induction
Mango is a terminal bearing crop and flowering is an important reproductive event in its life cycle especially for the production of fruits. In the flowering of mango, initiation is the first event that is responsible for mangoesto flower (Davenport and Núnez-Eliséa, 1997; Davenport 2000, 2003, 2009) [35, 32, 38]. In the process of floral initiation the onset of shoot development, regardless of theevocation shoots. In the leaf primordia (vegetative shoots), lateral meristems (generative shoots) or both (mixed shoots) in the nodes of the resting buds this process involves the elongation and division of cells. After that more nodes are formed in apical meristems through cell divisions (Davenport, 2007, 2009) [33, 38]. So many anthropogenic factors as pruning, irrigation schedule, application of nitrogen substances and/or fertilizers and exposure to ethylene are also responsible for the initiation of floral parts in mango (Davenport, 2009) [38]. According to Davenport (2007, 2009) [33, 38] shoot initiation (initiation of bud break must occur before induction) in mango can determine the type of shoot to be evoked in those resting buds. Formation of reproductive, vegetative, or mixed shoots

by different physiological events. A proposed model of floral induction have been developed by (Abdel Rahim et al., 2011) [1] showed through a flow chart in the following fig.
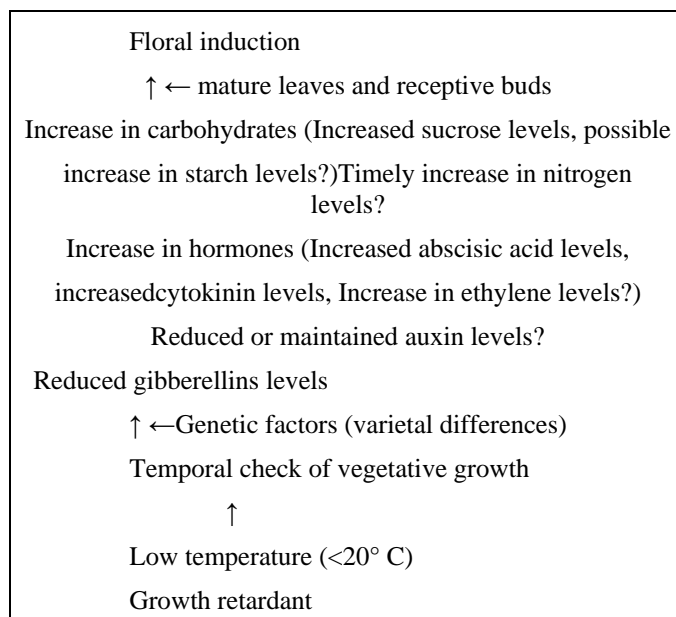
Floral induction

↑ ← mature leaves and receptive buds

Increase in carbohydrates (Increased sucrose levels, possible increase in starch levels?)Timely increase in nitrogen levels?

Increase in hormones (Increased abscisic acid levels, increasedcytokinin levels, Increase in ethylene levels?)

Reduced or maintained auxin levels?

Reduced gibberellins levels

↑ ←Genetic factors (varietal differences)

Temporal check of vegetative growth

↑

Low temperature (<20° C)

Growth retardant

Fig: Proposed model for floral induction in mango

Flower Bud Differentiation
Partitioning of metabolites from source to sink involved in the process of fruit bud differentiation. This process is generally influenced by crop load (Scholefield et al., 1986; Jannoyer and Lauri, 2009; Shaban, 2009) [76, 50, 79] bearing habit, genetic character (Smith-Ramírez et al., 1998; Marco and Páez, 2002) [90, 60], age and size of shoot (Ramírez and Davenport, 2012) [72] and other plant factors. Besides the above factors, fruit bud differentiation is also influenced by some climatic factors such as temperature, water stress, and photoperiod. One season old shoots differentiates for the fruit-bud-differentiation which starts from 5 to 6 months before the actual flowering. Different times of fruit bud differentiation have been reported by different workers in different places of world as well as in different conditions of India (Palanichamy et al., 2011) [68]. Chowdhary and Rudra (1971) [26] reported a direct relationship of the number of shoots growing in one season to the subsequent spring for fruit bud differentiation. They also informed that one season old shoots or five to six months old shoots perform the fruit-bud differentiation in mango.

Environmental factors and photoperiod in floral induction
Temperature plays vital role in growth and developmental activities of mango (GalánSaúco, 1999; Corbesier and Coupland, 2006) [27]. Temperatures rarely go below 18 ℃ to 20 ℃ in the low latitude, humid tropics; hence, the flower production is thought to be produced at a constantly low, basal level in order to induce flowering. Mango flowering only occurs in tropical warm temperatures in initiating shoots of stems that have achieved sufficient age since the previous vegetative flush i.e. four to five months depending upon cultivar (Davenport, 2003) [32]. Cool temperature is a prerequisite for flowering in the tropical evergreen mango tree, there are some important interactions with vegetative growth Vegetative and floral growth relationship and even vegetative activity is variable in tree to tree, year to years and among the localities (Scholefieldet al., 1986; Cull, 1987) [29, 76]. At the end of September especially with the advent of old and dry weather a sharp change in climatic conditions were

reported by Sen and Mallik (1941) [77] in Sabour conditions of Bihar which appeared to influence the fruit bud differentiation. Although a period of low temperature (less than 18 °C) during the pre-flowering period is thought to be involved in floral initiation (Davenport and Nunez-Elisea, 1997) [35] while factors are poorly understood, which determine the switching of floral induction from vegetative to reproductive mode. Flowering of mango occurs on sufficiently aged shoots in tropical areas where lacking of cool night temperatures (Nuñez-Elisea and Davenport, 1995) [64]. Davenport and Nuñez-Elisea (1997) [35] also observed that after a cool temperature regime of 18 °C day/10 °C night, 12-h photoperiod, was imposed for a minimum period of 3 weeks on trees bearing leaves at least 7 weeks old the induction of flower occurred in the apical buds of container-grown 'Tommy Atkins' mango trees. During the exposure to cool temperature regime growth of induced buds appeared which is necessary for floral induction, since buds resuming growth in warm (high) temperatures about 28 °C day and 22 °C night immediately after receiving an inductive, cool (low) temperature treatment produced a vegetative flush. While warm temperatures rather than a long photoperiod inhibit the flowering, cool temperatures rather than a short photoperiod induces the floral induction. Stems of mango are dormant between periodic and short episodes of growth as like in many tropical species. In subtropical conditions vegetative and reproductive flushes occur during clearly defined seasons in response to prevailing temperatures at the time of shoot initiation (Nunez-Elisea et al., 1996; Davenport and Nunez-Elisea, 1997) [34, 35]. Different workers (Singh and Khan, 1940; Naik and Rao, 1942; Sen, 1943; Gandhi, 1955; Burns and Prayag, 1921; Singh, 1959) [81, 61, 78, 46, 14, 84] at the different environmental conditions have reported different periods of occurrence of primary and extension growth which depends upon the variety and local conditions also where they worked.

Physiological approaches in floral induction
Hormonal concept of floral induction in mango
According to the proposed hypothesis of Chandler (1950) [24] with the beginning of cell division 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 auxiliary 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. Singh (1961) [82] showed that the regular bearing cultivars such as 'Neelum' were capable for synthesis of flower inducing hormone in the shoots with the newly merged leaves.

Auxin
In the floral induction of mango auxins may play a vital role and there is a little supporting evidence (Chadha and Pal, 1986; Hegele et al., 2006) [20, 47]. In relation to mango flowering the application and analysis of auxins in leaves, stems and shoots have been reported by many workers (Singh, 1961; Singh and Singh, 1963; Chacko et al., 1972b; Bakr et al., 1981; Pandey and Narwadkar, 1984; Chen, 1987; Paulas and Shanmugavelu, 1989) [85, 89, 19, 8, 69, 25, 71] in relation to mango flowering. Davies (1995) [41] reported that inhibition of shoot initiation and apical dominance by preventing auxiliary bud break due to the presence of auxins. Chacko (1968) [15]

reported that in the shoots of 'Dashehari'a high level of auxins-like substance were found, which were expected to flower. Another work has been done by same worker on the naturally occurring growth substance;he reported that the presence of a zone on paper chromatogram which contains growth promoting substances in the shoots of 'Dashehari' and 'Totapuri Red Small' mango cultivars, and that growth promoting substance has similar biological propertiesto that of the auxins. The shoots from 'on' year 'Dashehari' and 'Totapuri Red Small' trees, that shoots initiated the floral buds during the experimental period which had high level of growth promoting substances during the flower-bud initiation period than the shoots of 'off' year 'Dashehari' cultivar of mango trees which remained vegetative.

Cytokinin
Several workers studied on the relationships between flowering of mango cultivars and the endogenous cytokinins level in the shoot tips (Agarwal et al., 1980) [4], in leaves (Paulas and Shanmugavelu, 1989) [71] and xylem sap (Chen, 1987) [25] during 'on' and 'off years from September to February. They also reported the effect of cytokinin on bud break and shoot development, including zeatmribo side and zeatin; eleven other cytokinins-like substances were also isolated during the 'on' year. In the 'on' year higher concentration of Cytokinin was observed at the time of flower bud differentiation during December and February however, the Cytokinin level was lower during the 'off' year. As per these results high levels of endogenous cytokinins in shoot tips is associated with flowering in mango. Bangerth et al. (2004) [9] observed that the increased level of cytokinin in mango stem buds during the exposure to cool and flower inductive temperatures.

Gibberellins
It is very difficult to interpret the reports of endogenous gibberellins in mango tissues, especially in buds with respect to a regulatory role in bud break or flowering. GA_3 inhibition in mango may cause the development of floral inductive conditions from vegetative buds, and this is also correlated with the applied concentration (Kachru et al., 1971, 1972) [51, 52]. In the apical buds for 6 months prior to the flowering season in the 'off' year of an irregular bearing mango cultivar the estimated levels of gibberellins were reported to be higher as compared with in the tree during the 'on' year (Pal and Ram, 1978) [67]. A study of Chacko (1968) [15] showed that higher concentration of gibberellins-like substance in the shoot extracts of 'off' season 'Dashehari' cultivar of mango tree in comparison to those of 'on' season trees, as reported by Singh (1959) [84] which were differentiating fruit of grafted seedling and was due to its higher concentration of endogenous gibberellins (Singh, 1971) [82].

Ethylene
Endogenous ethylene involved in flowering and it is supported by the occurrence of symptoms of ethylene production in the observations which are indirectly linked with it. Davenport and Núñez-Elisea (1990, 1991) [36, 34] observed that at the time of inflorescence initiation in mango, occurrence of extrusion of latex from terminal buds, and during the expansion of the panicle epinasty of mature leaves near the apex also observed. Both the symptoms of plants relate to high ethylene levels (Abeles, 1973) [3]. Saidha et al. (1983) reported that the endogenous leaf ethylene production is gradual increased, when the period is reached at the season

of floral initiation. Stems which produce reproductive shoots, produced five-fold higher ethylene that resting stems.

Florigenic promoter

Lang (1952) [56] defined initiation as the differentiation of floral primordia in buds following inductive events resulting in formation of a florigenic promoter (florigen) in leaves that is translocated to buds. Existence of a florigenic promoter (FP) that is continuously synthesized in mango leaves and induces flowering and which was supported by numerous studies (Ramírez and Davenport, 2010) [73]. Long distance transport experiments was done by Davenport et al. (2011) [39], they demonstrated that the florigenic promoter in one leaf can be translocated from a donor stem across the divided branches to induce flowering in as many as five leafless receiver stems located as far as 100 cm distant. The florigenic promoter moves in phloem from leaves to receptive buds this is indicated in this result also.

During the exposure to cool night temperatures (below 18 °C) the putative floral promoter seems to be up-regulated, there appears to be a base level present at all times regardless of temperature. A flowering stimulus is synthesized in leaves which induce floral initiation in buds (Sachs, 1865) [74]. In photoperiodic herbaceous plants the hormonal theory of flowering was formed by Chailakyan's experiments in 1936 (Chailakhyan, 1936a, b, c) [21, 22, 23]. According to Davenport (2007, 2009) [33, 38] the Florigenic promoter protein has been known to induce flowering in woody angiosperms. Davenport et al. (2006) [40] with an experiment reported that, a mango plant requiring cool temperature (LT) for floral induction (FI) they found that LT induced a substance that was transported via the phloem into lateral buds in treated leaves where it caused FI and thus many characteristics of this substance match with "florigen". Davenport et al. (2006) [40] studied on the movement of a putative florigenic promoter from leaves to buds in two cultivars of mango over two flowering seasons through examination of the minimum number of leaves on each stem necessary for floral induction and movement of this component over various distances from stem to stem in isolated branches. The minimum number of leaves on individual stems necessary to induce flowering was less than 1/4 of a cross-cut leaf per stem. The putative florigenic promoter moved from donor stems bearing as few as one leaf to induce flowering in five receiver stems located as far down branches as 100 cm from the donor stem. The floral promoter appears to be located in the leaves of mango and it is transported probably via phloem to buds (Davenport and Núñez-Elisea, 1990; Núñez-Elisea and Davenport, 1989, 1992; Núñez-Elisea et al., 1996) [36, 62, 88] and it also is graft transmissible (Kulkarni, 1991) [55].

Inhibitors

Because of the presence of floral inhibitors in new young leaves (Kulkarni, 1991) [55] it is commonly accepted that chances for flowering are increased as the terminals become more mature (Scholefield et al., 1986) [76]. Singh (1971) [86] reported that for checking the vegetative growth of mango, inhibitor might be of help by providing suitable conditions for flower-bud-initiation. An inverse correlation has been observed between the concentration of the inhibitors in shoot and vegetative growth and as a result a position association between the level of inhibitors and flowering of mango cultivar 'Langra' (Chowdhary and Rudra, 1971) [26]. Some inhibitors similar to abscisic acid have been reported by Chacko (1968) [15] in mango shoots. Relatively higher levels of this inhibitors during the flower-bud-initiation in the 'on'

year shoots of 'Dasheheari' and 'Totapuri red Small' trees had found than the shoots of 'off' year trees of 'Dasheheari', it indicates that in the flowering of mango the inhibitors might be actively involved. A correlation has been observed by Das Chowdhury (1969) [31] between the level of inhibitor (abscisic acid) and growth of the twigs of mango cultivar 'Langra'. Davenport and Nunez-Elisea (1997) [35] proposed that separate mechanisms are associated with the initiation and induction events of mango and inhibition of initiation of bud break regardless of shoot type evoked may be by GA3. Núñez-Elisea and Davenport (1991b) [34] reported that exogenously applied gibberellic acid (GA3) inhibits the flowering of mango.

Photosynthesis and gas exchange parameters in floral induction

Shivashankara and Mathai (2000) [80] studied gas exchange parameters such as photosynthetic rates at different carbon dioxide concentrations, stomatal conductance and internal carbon dioxide concentrations in flowering and non-flowering branches of regular and irregular bearing cultivars of mangoTotapuri and Langra respectively. They found that photosynthetic rate and stomatal conductance were higher in non-flowering branches as compared to the flowering ones, in both cultivars. This reduction in photosynthetic rate was not due to variation in the water status of the leaves, since relative water content (RWC) of the leaves in both types of branches was not significantly different. Hence, the reduction in photosynthetic rate could be mainly due to the reduction in carboxylation efficiency and this reduction in carboxylation efficiency probablyis due to the presence of inhibitors in the leaves of flowering branches. Urban et al. (2004) [95] observed that leaves close to swelling floral buds, inflorescences and panicles bearing set fruits had substantially lower values of both $NetCO_2$ assimilation rate (A_{net}) and stomatal conductance (g_s) than vegetative shoot leaves. Net CO_2 assimilation rate was higher in leaves close to reversing inflorescences than in leaves close to inflorescences or panicles bearing set fruits, whereas there were no differences in stomatal conductance (g_s). It was further found that the intercellular CO_2 concentration changed little over time in either vegetative shoot leaves or leaves close to inflorescences. Intercellular CO_2 concentration was lowest in leaves close to reversing inflorescences. During the floral development period decreases in net photosynthetic assimilation have been reported in mango by Shivashankara and Mathai (2000) [80]. Significantly low Net photosynthetic rates (PN) were found in flowering branches whereas higher Net photosynthetic rates (PN) were reported in the non-flowering ones in mango.

Biochemical mechanisms in floral induction
Role of carbohydrate

Singh (1978) [87] observed that older and more mature flushes accumulate sufficient reserves of carbohydrates to attain physiological maturity required for flower bud differentiation. Paulas and Shanmugavelu (1989) [71] found that leaf close to inflorescence has considerably low leaf starch concentration during the floral period; from floral bud swelling to fruit set leaf starch was globally higher than at any other period of the year, regardless of leaf position with respect to inflorescences, confirming previous observations on mango. Although alternate bearing is the major problem of mango and one of the factors responsible for biennial bearing in mango is the exhaustion of the carbohydrate supply by fruiting which also plays an important role in floral induction (Chacko and Randhawa, 1971) [18]. Low starch contents in vigorously growing mango cultivars have been reported by (Whiley et

al., 1989 Whiley et al., 1988) [96, 97] and floral initiation resulted as the diversion of assimilates from shoot apices to floral primordia. According to Kalayanaruk et al., 1982 [53] and Chacko, 1986 [16] carbohydrate reserves were directly correlated with flowering in mango tree. Increased concentration of all carbohydrates and the high C: N ratio which is caused by the girding treatmenthas favourable effect on the initiation of floral parts (Das Chowdhury, 1969) [31]. Carbohydrates are gradually stored in the wood of plant and the roots of mango trees in month May-June duringthe development of flower bud.

Role of phenols
Patil et al. (1992) [70] estimatedthat the total free phenols and activity of polyphenol oxidase diurnally types of fruit bud of 'Alphonso', mango cultivar during the fruit-bud-differentiation. Phenolic content of fruit buds was stable in undifferentiated (or) scar buds while it was increased steadily with advancing Flower bud differentiation. Polyphenol oxidase activity was higher before and during Flower Bud Differentiation than the afterwards.

Role of amino acids
Chowdhary and Rudra (1971) [26] on the contrary, reported theincrement in the concentration of all the free amino acids appreciably and due to the changes occurring in the concentration of arginine and histidine. The majorchanges in the total free amino acids were also reported at ripeness-to-flower stage. Another worker Suryanarayana (1978) [91] reported that, during the month of April the levels of all (12) amino acids in leaf and stem were very high, but after that it decreased gradually, and during or just preceding flower bud formation stage the concentration of amino acids reached at the lowest level in all the four cultivars (Mulgoa', 'Banganapalli', 'Neelum' and 'Banglora) during April-Jan. in each season. After this stage, during the period of inflorescence development all amino acids tended to increase.

Role of enzymes
Some enzymes such as ent-kaurene oxidase (KO) and entkaurenoic acid oxidise are the major site for the blocking of gibberellins biosynthesis by triazoleshas important role in these events which are closely related to the floral induction (Dalziel and Lawrence, 1984; Henry, 1985) [30, 48]. Influence of gibberellins could be due to inhibition of gibberellins biosynthesis because of the triazoles rather than amplify the action of the putative florigenic stimulus in order to achieve the flowering response (Davenport and Núñez-Elisea, 1997) [35]. The activity of Polyphenol oxidise activity was also reported to be higher before and during the Flower Bud Differentiation than the afterwards.

Molecular advancement in floral induction of mango
Advancement made recently in the decipheration of the mechanisms of molecular genetics that result in the morphogenetic transition from vegetative to a reproductive stage (Bernier and Pe'rilleux, 2005; Tan and Swain, 2006; Corbesier et al., 2007) [11, 93, 28]. A morphogenetic transition of stem cells in apical as well as in lateral central meri stems into differential bud cells constituted by floral induction (FI) in mature fruit trees. The activation and transcription of a great number of genes were implied by this transition (Boss et al., 2004) [12], which are controlled by various exogenous or endogenous factors in most of the annual or biennial (a/b) plants. The knowledge about how a tree attains this trait is

very less, but it may be a promising trait by maintaining particular genes in a silent (non-accessible to floral promoters) state. Some floral-repressing genes, such as FLC or other similar genes have been long time transcript for achieving this. Bangerth (2009) [10] reported that the prevention of transcription of floral inducing genes through DNA methylation, the involvement of micro RNAs or similar non coding RNA species, particular histone modifications and chromatin re-modeling. With the recent advancement in molecular approaches in floral induction a discovery in Arabidopsis phloem in which Constans and floral signaling gene, FT have been isolated (Abe et al., 2005; An et al., 2004; Ayre and Turgeon, 2004; Takada and Goto, 2003; Wigge et al., 2005; Yamaguchi et al., 2005) [99, 6, 7, 92, 98, 32]. If these genes are present and expressed in mango in order to explain the requirement for such a small amount of signal to induce flowering, for this process some workers sought for determination. A gene called MiCOL (CONSTANS-like) has been isolated from the leaf of mango tree in addition, and for this, there is only one leading published report on the molecular basis of mango floral pathway (Davenport et al., 2006) [40]. In Arabidopsis the induction of a floral signaling mRNA (FT) that is synthesized in leaves and transported in phloem to buds for initiation of flowering and this process has been done by Constans gene which is widely conserved in plants. A Constans-like Mangiferaindicagene (MiCOL) was characterized which was isolated from mango (Reference).At the protein level, MiCOL was 79%identical to MdCOL2, 76% toMdCOL1 from apple and62% to AtCO from Arabidopsis. Until now no FT-like gene has been identified in mango plants. Currently some workersare trying to determine and to rescue Arabidopsis constans mutant plants with the MiCOL gene, if transcription rates correlate with cool temperatures in mango plants (Davenport et al., 2011) [39]. In addition, a Flowering Locus T (FT) gene in mango which is responsible for the synthesis of the protein FP isolating and great efforts have been made by Davenport (2007) [33], without any success till date.

A study by de los Santos-Villalobos et al. (2012) [43] for designing two pairs of primers to amplify fragments of FT transcripts from M. indica by using an alignment of 41 amino acid sequences of this transcript which are belonging to fifteen different species of different angiosperms. Designed primers of amplified fragments are FTf1/FTr2 which was approximately 210 and FTf2/FTr2 was about 150 bp. Sequencing were done by Sanger platform and then obtained sequences were analyzed and compared with those of FT deposited in the NCBI (National Centre of Biotechnology Information) Gene Bank database, by using BLAST (Basic Local Alignment Search Tool), from M. indica; FT transcripts of 207 bp (Accession No. JX316911) and 147 bp (Accession No. JX316912) showed high identity 86% and 84% with FT of Populusnigra, respectively. Limitation in the development of efficient models and alternatives to enhance flowering for the higher yield and better crop productivity occurs when they are demanded for global market and this happen because, mango plants as well asin other economically important angiosperms a floral integrator gene Flowering Locus T (FT) and its function have not yet been identified so far (Lopez and Runkle, 2005) [58].

Conclusion
Floral induction in mango is very critical stage and play vital role inproducing the crop and it is also indirectly related to the overall productivity of mango. The first step in the induction

of flower is initiations which may lead to flowering. A number of factors are involved in the floral induction of mango such as age of the shoots, climatic conditions, physiological, biochemical conditions. In addition, anthropogenic factors such as pruning, irrigation, application of nitrogenous substances and/or fertilizers and exposure to ethylene can also stimulate the floral initiation. Although a period of low temperature (less than 18 ^{0}C) during the pre-flowering period is thought to be involved in floral initiation. Some floral promoter and some inhibitors are also involved in the initiation of flowering of mango. Likewise a flowering stimulus is synthesized in leaves which induce floral initiation in buds of mango. Relatively higher levels of some inhibitors (abscisic acid) was recorded during the flower-bud-initiation in the 'on' year shoots of mango trees compared to shoots of 'off' year trees. It indicates that in the flowering of mango, promoters and inhibitors might be actively involved. Significantly low net photosynthetic rates were found in flowering branches whereas higher net photosynthetic rates were reported in the non-flowering ones in mango. This indicates that photosynthetic rate also play important roles in the floral induction of mango. Some bio chemicals are also associated with floral induction of mango. Sufficient reserves of carbohydrates to attain physiological maturity required for flower bud differentiation accumulated in the older and more mature flushes, which shows that age of the shoot is also important for floral induction. The activity of Polyphenol oxidase activity was also reported to be higher before and during the Flower Bud Differentiation than the afterwards. Some enzymes such as ent-kaurene oxidase (KO) and entkaurenoic acid oxidase are the major site for the blocking of gibberellins biosynthesis by triazoles which has important role in these events which are closely related to the floral induction. Enzymes are also associated with floral induction. A prospective may be made, if the Arabidopsis genes (*Constans* and floral signalinggene, *FT*) are inserted and expressed in mango in order to explain the requirement for such a small amount of signal to induce flowering. This advancement may be milestone in the floral induction of mango, but this work is in progress (Reference). In addition, a gene *MiCOL* (*Constans*-like) has been also isolated from the leaf of mango tree on the molecular basis of mango floral pathway, while in mango plants as well as in other economically important angiosperms a floral integrator gene *Flowering Locus T* (*FT*) and its function have not yet been identified so far. As a final consequence of efforts to elucidate the mechanisms of floral induction in mango becoming clearer at the physiological, biochemical and molecular levels resulting in a better understanding is critically reviewed here.

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