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RK Jhade
Scientist (Horticulture), JNKVV, Krishi Vigyan Kendra, Chhindwara, Madhya Pradesh, India

AD Huchche
Principal Scientist (Horticulture) ICAR-Central Citrus Research Institute, Nagpur, Maharashtra, India

SK Dwivedi
Principal Scientist (Plant Physiology) Department of Plant Physiology, College of Agriculture, JNKVV, Jabalpur, Madhya Pradesh, India

Correspondence
RK Jhade
Scientist (Horticulture), JNKVV, Krishi Vigyan Kendra, Chhindwara, Madhya Pradesh, India

Phenology of flowering in citrus: Nagpur mandarin (*Citrus reticulata* Blanco) perspective

RK Jhade, AD Huchche and SK Dwivedi

Abstract
Citrus (*Citrus spp.*) is one of the main fruit tree crop grown in many tropical and subtropical regions in the world. Flowering is a cascade reaction consisting of several steps. Flower formation is a transition phase in the life cycle of a plant. Citrus species usually produce a large no. of flower over the year the floral load depends on the cultivar, tree age and environmental conditions. Flowering is the first of several events that set the stage for citrus production each year. It also influences the quality and quantity of fruits. The flowers and fruit of trees senesce when the concentration of auxin decreases and the concentration of abscissic acid (ABA) increases. Endogenous hormones and their balance play a modulating role in the mobilization of nutrients to the developing organs. Temperature, florigenic promoter, inhibitors, auxin, cytokinin, gibberellin, carbohydrates, amino acids, phenols, enzymes and genetic factors play important role in the floral induction of citrus. The elements and mechanisms whereby endogenous and environmental stimuli affect fruit growth are being interpreted and this knowledge may help to provide tools that allow optimizing production and fruit with enhanced nutritional value, the ultimate goal of the Citrus Industry. To obtain higher fruit yield during a particular period, the citrus (Nagpur mandarin) plants are given a resting period by which the natural tendency of the tree is altered with artificial means. It is done by withholding of water for about 30 to 40 days in advance of the normal flowering, root exposure and also use of chemicals is known as *bahar* treatment.

Keywords: phenology, bahar, flowering, retardant, mandarin

Introduction

India ranks 3rd in world production of Citrus with an area of 10.55 million hectares (14.9% of total fruit area) and production of 12.74 million tonnes (12.5% of total fruit production) with a productivity of 10.30 tonnes/ha. The total production of oranges in India is 3431.4 thousand MT (3.9% of total fruit production) from an area of 330.0 thousand hectares (4.6% of total fruit area) with a productivity of 10.4 MT/ha.

Maharashtra is the main mandarin producing state in the country having the highest area of 0.135 million ha (40.9%), an estimated production of 7.42 million tonnes (21.61%) and a productivity of 5.5 MT/ha. Nagpur *Santra* (Nagpur mandarin) is a finest variety and very popular in India as well as in world for its good quality fruits. The state of Madhya Pradesh is also the main mandarin producing state in the country having the area 0.052 million ha (15.91%) with an estimated production of 8.94 million tonnes (26.06%) and productivity of 17.0 MT/ha (NHB, 2014).

Citrus is an important genus of the family *Rutaceae* in the plant kingdom. Mandarin botanically belongs to the Kingdom: Plantae, Division: agnoliophyta, Class: Magnoliopsida, Subclass: Rosidae, Order: Sapindales, Family: Rutaceae and Genus: *Citrus,* Species: *reticulate.* Mandarin is a Citrus fruit of the species *Citrus reticulata*. It is distinguished from other Citrus species by the relatively loose skin of the fruits, the relative ease with which the segments can be separated and (in most cultivars) the green cotyledons. Citrus fruits are also classified as hesperidiums, berries of very special organization characterized by a juicy pulp made of vesicles within segments. In a specific way the mandarin fruits are subglobose having average weight 110-125 gm, rind medium thick, fairly loosely adherent, surface is also relatively smooth but, segments found in 10-15 number and number of seeds 1-2 per segment, colour of peel pale orange yellow. Fruits have mild flavour, excellent quality, juicy, TSS 10-12^0 Brix, and acidity 0.50-0.70%. The fruit consists of three layers. The outer yellow/orange peel is with oil glands which exude the essential oils, producing the typical orange odour. The mesocarp is whitish thread like.

The endocarp consisting of 8 - 10 segments is filled with juice sacs (vesicles). Mandarins are rich source of vitamin C in the form of ascorbic acid (31– 54 mg per 100 g of edible portion) and calcium (25 – 46 mg per 100 g of edible portion). One orange actually has all the vitamin C that one needs for the day (Morton, J. 1987) [27].

Citrus Phenology

"Phenology refers to "the study of the timing of recurrent biological events, the causes of their timing with regard to biotic and abiotic forces, and the interrelationship among phases of the same or different species" Badeck *et al*., (2004) [4].

Citrus is produced commercially in over 100 countries worldwide. The major growing regions are located primarily between 40^0 north-south latitude where minimum temperature is generally greater than 20°F. Within these latitudes there are several important climatic areas that affect the growth and development, yields, and fruit quality of Citrus. In India, Citrus is grown in a variety of agro–climate right from northern plain and central highlands having hot semi-arid eco-region with alluvium derived soils to central hot sub-humid eco-region with black and red soils and humid eco-region with red and lateritic soils. The commercial cultivars namely Kinnow mandarin in north-west India, Darjeeling mandarin, Khasi mandarin in north-east India, Nagpur mandarin in Central India. Coorg mandarin in Coorg areas of South, sweet orange cultivars Mosambi in western Maharashtra and Sathgudi in Andhra Pradesh, acid lime in Tamil Nadu, Khera district of Gujarat and West Uttar Pradesh are commercially grown.

The flowering in Citrus under Indian conditions is induced through either low temperature stress or soil water deficit stress. In central India and South India in the absence of low temperature, the soil water deficit stress is adopted to induce flowering in the cultivars such as Nagpur mandarin, Mosambi and Sathgudi. Monselise (1947) [47] suggested that the cessation of root growth as a result of low temperature, water stress, weak rootstocks, and confined roots were necessary for floral induction.

The citrus plants flower and provide fruits throughout the year in central and southern India. However, it needs to be thrown into rest period so as to enable prolific harvest at a given time. Looking at patterns of precipitation in India, flowering can be induced during June-July (*mrig bahar*), September–October (*hasta bahar*) and January–February (*ambe bahar*) in areas having assured rainfall where precipitation is normally received in June and continues up to September. Citrus (specially in Nagpur mandarin) tree flowers throughout the year, but the peak flowering is observed in 2 season, *ambia* crop (January-february) and *mrig* crop (June-July). To obtain higher fruit yield during a particular period, the citrus fruit (Nagpur mandarin) plants are given a resting period by which the natural tendency of the tree is altered with artificial means. It is done by withholding of water for about 30-40 days in advance of the normal flowering, root exposure and also use of chemicals is known as *bahar treatment* or flower regulation.

Ambe Bahar: This is taken in the areas where, enough water is available during hot weather**.** In this bahar, flowering can be induced in January- February.

Mrig Bahar: In this *bahar*, flowering can be induced in June-July, coinciding with the outbreak of monsoon; this treatment is taken in the areas where, water is scarce during the hot weather.

Hastha Bahar: In this *bahar*, flowering can be induced in September – October, where the trees have to be made dormant during August–September. This is rather uncertain because of the rain that occurs during this period. Due to this reason *hastha bahar* is very difficult. This *bahar* is generally followed in pomegranate.

Bahar	Flowering Time	Fruiting Time	Quality
Ambe bahar	January- February	October-November	Good
Mrig bahar	June–July	February-March	Excellent

Flowering in Citrus

Flowering is usually evaluated when the morphological differentiation of flower organs is clearly recognizable, or even upon the opening of flowers. However, the whole phenomenon of flowering starts with flower induction, followed by the initiation of flower primordia and the development of these primordia into mature flowers, each of these steps being amenable to an independent regulation. As in all plants, in *Citrus* there are three factors which detennine the final yield: (i) the number of flowers formed. (ii) the percentage of fruit set. and (iii) the size ultimately reached by the fruits. Each of these factors is subject to complex regulation, involving hormonal and nutritional aspects, and the three corresponding developmental stages are interrelated. Either directly or through their influence on the general status of the tree.

Citrus trees, once past the juvenile phase, bloom every year. Annual flowering of adult trees is affected by several exogenous and endogenous factors. In citrus, cool temperature can induce flowering, as in most tropical and subtropical trees (Inoue 1990, Lenz 1967, Moss 1976, Nishikawa *et al.* 2007, Wilkie *et al.* 2008) [19, 24]. In Satsuma mandarin, floral induction occurs in trees exposed to 15°C for more than 1.5 months (Inoue 1990b, Nishikawa *et al.* 2007) [19]. Trees generally remain in the vegetative growth phase until the trees are exposed to temperatures of less than 25°C (Inoue and Harada 1988) [20]. Under field conditions, the trees are exposed to cool temperature during fall, during which floral induction proceeds. The plant growth regulators stimulate the abscission in the flowers that causes heavy flower drop.

Naik, (1949) [49] In South India, where there is no well – defined winter with very low atmospheric temperature, the flowering season is longer and not very distinct. It is very common to get two crops, occasionally three also, in many Citrus types grown in South India. Erickson and Brannaman (1960) [10] and Goldschmidt and Monselise (1977) [12] reported, for example, that sweet oranges (*C. sinesis*) may develop 2,50,000 flowers per tree in a bloom season although only a small amount of these flowers (usually less than 1%) becomes mature fruit. Hayes (1970) [16] reported that intensity of flowering is influenced greatly by the period of growth cessation, and the amount of the proceeding bloom or crop. In the North Indian conditions, where the temperature goes down substantially during winter months, major bloom of almost all the species occurs during early spring (February-March) when the atmospheric temperature starts rising after the cold winter and soil moisture condition also improves.

Goldschmidt and Huberman (1974) [16] reported that Citrus species show a relatively long juvenility period (two to five years) before the trees reach the mature stage to produce flowers. The inflorescence developed in Citrus may be either leafless or leafy and these may carry a single flower or several of them. The ratio of each kind of inflorescence in the tree varies with flowering intensity and cultivar.

Monselise (1996) [29] observed that Citrus species usually produce a large number of flowers over the year. The floral load depends on the cultivar, tree age and environmental conditions. Goldschmidt *et al*. (2013) [14] suggested that an overview of the conceptual and methodological changes in Citrus developmental research during the past half century is provided. Beginning with the hormonal era, the extensive use of plant growth regulators (PGRs) is described and the presumed role of gibberellins in various stages of the reproductive processes is emphasized. Introduction of the source sink concept opened the way for alternative, carbohydrate-mediated explanations of productivity and alternate bearing. The potential role of ethylene in Citrus abscission and fruit ripening is reviewed. The recent adoption of genetic–molecular approaches paves the way for deeper understanding of Citrus developmental enigmas. Several mechanisms have been proposes to explain the flowering phenomena in Citrus over the past years. Many factors contribute to the flowering mechanism in Citrus that are attributed to the following effects either alone or in combinations.

The inflorescence developed in citrus may be either leafless or leafy and these may carry a single flower or several of them (Goldschmidt and Huberman, 1974) [16]. The ratio of each kind of inflorescence in the tree varies with flowering intensity and cultivar. For example, high flowering intensities are generally related to high rates of leafless floral sprouts although some cultivars, such as Satsuma (*C. unshiu* Marc.) that tends to produce only vegetative shoots and single flower inflorescences, may show some particularities. Citrus species usually produce a large number of flowers over the year. The floral load depends on the cultivar, tree age and environmental conditions (Monselise, 1986) [30]. It has been reported, for example, that sweet oranges (*C. sinensis*) may develop 250,000 flowers per tree in a bloom season although only a small amount of these flowers (usually less than 1 %) becomes mature fruit (Erickson and Brannaman, 1960; Goldschmidt and Monselise, 1977) [10, 12]. Thus, flowering represents a great input for citrus trees and to some extent even a waste of resources.

Flowering Induction

In subtropical regions, citrus major bloom occurs during the spring flush along with the vegetative sprouting. Under these environmental conditions, flowering takes place after a period of bud quiescence and the exposure to the low temperatures and short days of winter. Generally, summer and fall flushes are less intense and produce almost exclusively vegetative shoots. The importance of temperature as a major factor of flower induction is well established and has been recognized for a long time (Moss, 1969; Altman and Goren, 1974; Guardiola *et al*., 1982; Valiente and Albrigo, 2004; Nebauer *et al*., 2006) [31, 32, 3, 15, 53, 38]. Several authors have proposed that low temperatures may have a dual effect releasing bud dormancy and inducing flowering (Southwick and Davenport, 1986; García-Luis *et al*., 1989, 1992; Tisserat *et al*., 1990) [43, 11, 46]. Moreover, temperatures under 20ºC have been demonstrated to contribute to flower bud induction in a time dependent manner (Moss, 1969; Southwik and Davenport, 1986; García-Luis *et al*., 1992) [31, 32, 43,]. In tropical climates, however, bud sprouting and flowering come about without interruption throughout the year although the main bloom still occurs during the spring (Monselise, 1985; Spiegel-Roy and Goldschmidt, 1996) [33, 34]. In contrast to the sub-tropical stimuli, in tropical conditions citrus apparently flower in response to drought periods. In addition to low temperature, water deficit has also been recognized for a long time as another strong inductor of flowering in citrus (Cassin *et al*., 1969) [8]. Moreover, water deficit has been proved to increase the ratio of floral shoots and the total number of flowers (Southwick and Davenport, 1986) [43]. It should be noted that several citrus species and varieties also show a wide range of behaviors regarding both flowering time and response to the inductive conditions. For example, lemon trees tend to show sparse flowering over the year even in subtropical conditions (Nir *et al*., 1972) García-Luis *et al*., 199392 and also exhibit higher floral responses to waters stress than to cold inductive temperatures (Chaikiatiyyos *et al*., 1994). This effect has been commercially used to induce off-season flowering (Davies and Albrigo, 1994).

Growth retardants for inducing flowering in citrus

Plant growth retardants are synthetic compounds, which are used to reduce the shoot length of plants in a desired way without changing developmental patterns or being phytotoxic. This is achieved primarily by reducing cell elongation, but also by lowering the rate of cell division. In their effect on the morphological structure of plants, growth retardants are antagonistic to gibberellins (GAs) and auxins, the plant hormones that are primarily responsible for shoot elongation. In the recent years, chlormequat chloride and paclobutrazol, growth retardants have been used with considerable success to induce early flowering for off-season production in several fruit crops.

Chlormequat chloride [(2-chloroethyltrimethylammonium chloride) is one of the retardant of plant Growth. It process against gibberellic acid inside the plant when absorbed by organs (root, stem and leaves).

Paclobutrazol [(2RS,3RS)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1H-1,2,4 triazol-1-yl) pentan-3-ol is also one of growth retardant which inhibits kaurene oxidase and thus blocks the oxidative reactions from ent-kaurene to entkaurenoic acid in the pathway leading to gibberellic acid.

The primary effect of paclobutrazol is to reduce canopy growth and direct nutrients and the carbohydrates synthesized into the leaves into fruit and seed production, rather than into non-productive leaves and stems. One method to manipulate flowering is to use the plant growth regulator, paclobutrazol. The post-harvest application of a small amount of paclobutrazol to the soil significantly promotes flowering and fruiting in the following year. Trials over the last three decades have shown the following benefits from the treatment:

- A significant increase in flowering leading to increased yields.
- The early flowering considerably enhanced fruit maturity. Treated trees flowered three to four weeks early, which reduced the time to fruit maturity by at least two weeks.
- Visually, the fruit developed a better external colour.

Thirugnanavel, R *et al*. (2007) [50] The study revealed that application 3 of GA 50 ppm in June + cycocel 1000 ppm in 3 September + KNO two percent in October showed better performance in delaying of flowering, number of flower shoot-1, initial fruit set, fruit retention, number of fruits and yield in acid lime. Mukunda Lakshmi *et al*. (2014) [35] reported that the foliar spray of GA3 (50 ppm in June followed by Cycocel 1000 ppm in September and KNO3 1% in October was found superior with respect to number of fruits per tree (529.34), fruit weight (41.12 g), yield (24.08 kg/ tree) and quality (juice content 34.34ml and TSS 6.920 Brix) during summer (2011-12 and 2012-13). However, the treatment with application of GA3 100 ppm in June and Cycocel 1000 ppm in September recorded highest benefit cost ratio of 2.42 followed by foliar spray of GA3 50 ppm in June and Cycocel 1000 ppm in September (2.19).

Jain *et al*. (2002) [21] observed that effect of paclobutrazol on growth, yield and fruit quality of lemon was studied during 1996-97 and 1997-98. The treatments consisted of 2 doses of paclobutrazol, i e 2.5 ml and 5.0 ml ai/tree, and the control and 8 months of application (September to April). The results indicated that the paclobutrazol 5 ml ai/tree in November reduced the shoot length, while various paclobutrazol treatments increased the total yield, fruit juice, TSS and ascorbic acid content. However, the total yield in summer was obtained in the control.

Yeshitela *et al*. (2004) [54] sugessted that the effects of paclobutrazol on the vegetative growth, reproductive development, total non-structural carbohydrate of the shoots, and nutrient mobilisation to the leaves of 'Tommy Atkins' mango *(Mangifera indica)* trees grown in the Rift Valley of Ethiopia were evaluated during the 2002/03 season. The results showed that application of paclobutrazol at rates of 5.50 and 8.25 g a.i. per tree both as a soil drench and spray applications were effective in suppressing vegetative growth compared with the control. Consequently, the trees from these treatments had higher total non-structural carbohydrate in their shoots before flowering. Compared with the control, trees treated with paclobutrazol had higher results for percentages of shoots flowering, number of panicles produced, percentages of hermaphrodite flowers, yield as well as quality of the fruit. Applications of paclobutrazol did not affect the leaf macronutrient content levels analysed (N, P, K, and Ca), and with the exception of manganese, the micronutrient (Cu, Zn, and Fe) levels of the treated tree's leaves were significantly higher than the control.

Tripathi and Dhakal *et al*. (2005) [51] suggested that the paclobutrazol applied on 17 July was the most effective in inducing early flowering at fourth week of December, which was 70 days ahead of normal flowering date. The subsequent applications on September, October and December also advanced flowering time by 59, 41 and 32 days, respectively. The earlier (July) application of paclobutrazol was superior among the treatments under Chitwan condition to induce and advance early flowering for offseason market.

Adil *et al*. (2011) [2] observed that the results implicated the positive role of paclobutrazol on floral induction of the two regular bearing mango cultivars, Baladi AbuZaid and Baladi Burai during off season. Similarly, prohexadione-Ca was effective in advancing off season flowering of the regular bearing mango cultivar, Baladi Elriah. The levels of cytokinins (zeatin (z) + zeatin-riboside (zr) and isopentenyl Adenine (i-Ade) + isopentenyl Adenosine (i-Ado) were generally increased during the floral induction period, while those of gibberellins and auxin (IAA) were decreased during the same period. Our results might implicated the possibility of inducing out of season flowering and thus extending the season of mango harvest under central Sudan conditions.

Cruz *et al*. (2011) [9] suggested that two-years-old olive plant variety Grappolo 575, were submitted to light pruning, removing apical dominance, before treatments application. The treatments were organized in a 4×2 factorial scheme, respective to four PBZ concentrations tested: 0, 200, 400 and 800 mg L-1 of PBZ and two plants groups, with and without pruning, in randomized block with four replications. Paclobutrazol concentrations tested did not affect the olive tree flowering. The plant vegetative growth was reduced until 60 days after paclobutrazol application. Pruning resulted in stimulation of emission of vegetative shoots and reduction of flowering. Phadung *et al*. (2011) [41] observed that the water stress and PBZ increased the leaf total non-structural carbohydrates (TNC) and the C/N ratio at the end of water stress, which then slightly decreased until the flushing period, while total nitrogen (TN) decreased and tended to increase until flowering. The results indicated that trees treated with PBZ had comparable flowering and TNC and C/N ratio values to the water stressed trees, while urea applied before water stress stimulated early flowering. Therefore, the application of PBZ and urea combined with water stress to induce flowering of pummelo trees may be a useful development for commercial production.

Martinez-Fuentes *et al*. (2013) [25] observed that the floral bud inductive period, PBZ promotes flowering in Citrus. PBZ significantly increased the percentage of sprouted buds and leafless floral shoots (both single-flowered shoots and inflorescences) and reduced the number of vegetative shoots. By contrast, heavy fruit load trees receiving the same amount of PBZ in the same season or at floral bud differentiation period scarcely flowered. Fruit nullified the effect of PBZ irrespective to treatment date (inductive period or bud burst) as well as the dose applied (1, 10 or 15 g tree−1) or the treatment method (soil application or canopy spraying). In conclusion, the effectiveness of PBZ in promoting flowering in Citrus depends on the fruit load since the tree showed a cultivar-dependant threshold value above which PBZ is unable to promote flowering.

Abolfazl *et al*. (2013) [1] suggested that the application of paclobutrazol significantly reduced the rate of vegetative growth by decrease of length of shoot and leaf and decreased of leaf number on plants. An effect of paclobutrazol on yield with increased size and fruit number on plant caused increased yield on plant. Paclobutrazol caused effects signification on fruit quality with increased of contain TSS and decreased TA. Lolaei *et al*., (2012 a,b) [1] reported application of paclobutrazol caused decreased of vegetative growth and increased of yield and signification effects of fruit quality. Similar results reported by authors.

Burondkar *et al*. (2013) [7] examined that the results of individual years and mean for three years revealed that significant earliness in flowering (85.4 day) and advancement in harvesting (82 day) was achieved with the application of PBZ on 15th May. PBZ application on 15th June was relatively less effective in inducing early flowering (56 day) and harvesting (69 days). However, the greater extent of flowering (72.23 %) and fruit yield per tree (40.72 kg/tree) were recorded with PBZ applied at recommended time *i.e.*, on 15th August. Individual fruit weight was higher in KNO3 sprayed tree in the months of August (268g) and September (265.5 g), whereas fruit T.S.S. was higher (19.37 ºBrix.) in trees receiving PBZ on 15th August. The findings of study indicated huge potential for realizing about 5-6 times higher returns from Alphonso produced in February-March months as compared to May harvest. Upreti *et al*. (2013) [7] suggested that the paclobutrazol has been found predominantly effective in the induction of early flowering and thus finding scope for off-season production in mango. The precise physiological mechanism regulating early floral induction is meagerly understood. The objective of the study was to examine the hormonal relationships associated with floral induction in mango following paclobutrazol treatment. The paclobutrazol applied as soil drench, @ 3.0 ml/m canopy diameter during the 3rd week of August advanced fruit harvest period by 22 days as compared to untreated trees by promoting early flowering. The C:N ratio in shoots, leaf water potential (w) and ABA content in the paclobutrazol untreated and treated trees increased progressively as shoots approached bud break stage. There was increase in C:N ratio and leaf w, by the paclobutrazol with drastic increase at the bud break. C:N ratio in shoot was positively related to ABA content in buds. Cytokinins – zeatin (Z), zeatin riboside (ZR) and dihydrozeatin riboside (DHZR) in buds increased consistently from 30 days before bud break till floral bud initiation. In paclobutrazol treated trees, increase in ZR and DHZR contents in buds were positively related to leaf w. GA_4, GA3, GA_7 and GA1 were the prominent GAs in the leaves and buds. In buds, these gibberellins followed trends opposite to that of cytokinins. The paclobutrazol treatment declined GA4, GA3, GA7 and GA_1 contents both in leaves and buds; with buds being more receptive to paclobutrazol treatment. These results implicated that paclobutrazol besides affecting gibberellins also increases ABA and cytokinin contents concomitant with C:N ratio and leaf w in mango buds to elicit flowering responses.

Sathiyaraj *et al*. (2014) [42] observed that soil drenching of paclobutrazol at 2.5ml /m-2 of canopy diameter during the month of May for off season and August for the main season was effective in enhancing flowering earliness, increasing number of inflorescence, and reducing number of days required for flowering, flowering to fruit set, fruit set and yield tree^{-1}. Tamilselvi and Baskaran (2014) [45] suggested that paclobutrazol application at a concentration of 2.50 g a.i/tree increased Nitrogen content ofleaves at vegetative stage compared with the flowering and harvesting stages. This trend was continued for the two consecutive years. The N and K content of the leaves were increased by paclobutrazol application 3.75 g a.i/tree at vegetative stage compared to flowering and harvesting stages. Moreover predominantly, trees treated with paclobutrazol during main season recorded highest leaf nutrients content while which was low in off season. Srilatha *et al*. (2015) [44] revealed that the PBZ application recorded decline in gibberellin (GA3) contents and increase in abscisic acid (ABA) levels at 45 and 75 days after PBZ application compared to control. From the study, it was apparent that the pruning of trees to current season's growth and PBZ application are beneficial for regulating tree size, early flowering and advancing fruit harvest in mango and such effects are mediated through increase in ABA and decrease in GA3 contents.

Hormones in citrus flowering

Gibberellin treatment is a common agricultural practice that is currently used to inhibit flowering in citrus trees. Applications of gibberellic acid during citrus bud development have been widely shown to inhibit flower production (Guardiola *et al*., 1982) [15], leading to a greater ratio of terminal flowers in leafy shoots and consequently a higher fruit development. This observation is in contrast to the reported flowering promoting effect of gibberellin on annual plants such as *Arabidopsis thaliana*. Despite the absence of a mechanism to cope with this observation, the flower repressing effect of gibberellins is corroborated by treatments with the inhibitor of GA biosynthesis paclobutrazol, which consistently induces flowering when applied to the field. Furthermore, the treatments with GA synthesis antagonists are not effective when GA is already present at high levels. Bud treatments with gibberellins also reduce summer bud sprouting (Lliso *et al*., 2004) [23]. Other growth regulators and phytohormones have also been assayed with variable results. Benzyladenine, for instance, has been suggested to have a specific effect on flower differentiation (Iwahori *et al*., 1990) [18] and to promote general bud sprouting *in vitro* (Altman and Goren, 1978) [39] and in whole trees (Nauer and Boswell, 1981; Lliso *et al*., 2004) [23].

According to Martinez *et al.* (2004) [22] flowering of Hernandina gets reduced by 25% and of Orogrande by 60% when GA3 (20-50 mg/ l) when given as a foliar spray (6 L per tree) to all the citrus trees. During bud development in citrus, the application of GA3 has shown to inhibit flower production (Guardiola *et al.* 1982) [15], leading to greater ratio of terminal flowers in the leafy shoots thus higher development of fruits (Iglesias *et al.* 2007) [17]. These results were also shown by use of ethychlozate and GA3 for flower induction in citrus fruits but GA3 caused inhibitory effect (Takahara *et al.* 2001) [47]. According to Ben-Cheikh *et al.* (1997) [5] gibberellins are the factors responsible for ovary transition. In vegetative organs, gibberellins activate the process of cell division and cell enlargement (Talon *et al.* 1991) [48] thus are also associated with initiation of growth (Talon and Zeevart 1992) [49]. Gibberellins reduce the flower production resulting in higher productivity of better quality fruits. It acts like a thinner agent but it also showed the ability to retain the flowers (Iglesias *et al.* 2007) [17] whereas 2,4-D delay or stimulate the abscission. Talon and Zeevart (1992) [49] reported that in citrus the reproductive processes are affected by plant growth regulators showing that regulatory mechanism being controlled by critical hormonal component.

Conclusion

Flowering in citrus crops is a least understood and fairly complex phenomenon. It is recurrent under tropical and subtropical conditions unless synchronized into a welldefined period of concentrated bloom by external conditions. It is the first step of sexual reproduction is of paramount importance in citriculture. The change from the vegetative state to the reproductive state is one of the most dramatic events in the ontogeny of a plant. Flowering leads to an exciting succession of events like anthesis, fruit set, fruit development, maturation and ripening. Flowers can potentially be produced throughout the year, but in most oranges and mandarins grown in temperate environments, the majority of flowers are produced during the spring flush. Thousands of flowers are usually produced on established trees, but only a relatively small proportion develops into fruit.The unusual reproductive biology of *Citrus* certainly brings new challenges in the analyses of genetic and phenotypic variation. In addition, all tree-specific traits controlling and influencing flowering, fruit development, abscission and ripening are also obvious major areas of research. The citrus productivity depends on various factors, among these the plant growth regulators holds a prime position. Plant growth regulators have been used in citrus fruit production for influencing flowering, fruit set and fruit drop and play a major role in fruit growth and abscission. These regulators have also been used to influence fruit quality factors.The use of plant growth regulators has become an important component in the field of citriculture because of the wide range of potential roles they play in increasing the productivity of crop per unit area. The plant growth regulating compounds actively regulate the growth and development by regulation of the endogenous processes and there exogenous applications have been exploited for modifying the growth response.

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