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# Alternate Bearing in Fruit Crops: Causes and Control Measures

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Alternate bearing (AB) is a phenomenon, common in fruit crops, is a concerned plant or branch or orchard does not bear a regular crop year-after-year rather heavy yields are followed by extremely light yield and vice versa. Based on the alternate bearing index, it is divided in four groups viz., no alternation, less alternate, high alternate, severe alternate. There are mainly two factors are responsible for alternate bearing i.e., exogenous and endogenous factors. Alternate bearing can be managed by cultural practices, selection of rootstocks, and selection of cultivars, chemical application and pruning at right time. Scrutiny of all of the factors are presented in this review to achieve consistent success in induction of flowering in perennial fruit crops. The information may pave way for better regulation of flowering shoots to enhanced fruit productivity in various fruit crops.

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## 1. INTRODUCTION

Alternate bearing is a phenomenon in which, plant or branch or orchard does not bear a regular crop year-after-year rather heavy yields are followed by extremely light yield and *vice versa.''* A biennial cycle is very usual so that ''on year'' (higher yield) ''off year'' (lower or no yield) and it may continue for subsequent years. "Alternate bearing is a widely spread phenomenon, wherein the cropping does not follow a systemic pattern and occurring in both deciduous and evergreen fruit plants. Long-term studies of the development of flowers and fruits have shown that individual shoots alternate between years when flowers and fruits are produced and years when only leaves are produced" [1,2]. It is found in most of fruit crops like *Olea europea* (Morettini 1950), *Mangifera indica* [3], *Malus x domestica* [4], *Litchi chinensis* [5], *Pistacia vera* [6], *Persea americana* [5], *Prunus armeniaca* [7], *Citrus reticulata,* [8], *Citrus sinensis* [9], *Pyrus communis* [4], *Carya illinoensis* [10], *Prunus domestica* (Courajou, 1978) and *Phoenix dactylifera.*

The theory that alternate bearing in individual tree occurs as a result of variations in local resource storage over years is supported by two observations firstly individual outgrowth, not branches or whole trees, gave rise to alternate leaf and fruit production each year and secondly, the majority of sugars produced by a leaf are translocate for only short distances to the adjacent fruit or branch tissues. Therefore depleted local resource storage following heavy flowering during next year only leaves are produced. Leaves pose lower carbohydrates and other resource demands than fruit and participate in increased local storage for the following year when flowers/fruits are produced.

## 2. ALTERNATE BEARING INDEX (ABI)

ABI is measure of a cultivars tendency to produce alternating high and low yield.

$$\mathbf{ABI} = \frac{\textbf{Yield (year 1)} - \textbf{Yield (year 2)}}{\textbf{Yield (year 1)} + \textbf{Yield (year 2)}}$$

The Biennial Bearing Index has been used in various fruit crops like in apple [11], mango [12], coffee [13], citrus [14], pecan [15], and pistachio [16]. To assign the role of flowering in the phenomenon, the name was later changed to "Modified Alternate Bearing Index" (MABI).

**Table 1. Based on the Alternate Bearing Index (ABI) cultivars of fruit plants are divided into following four classes**

| Class of cultivars | Range of ABI |
|---|---|
| No alternation | 0 |
| Less alternate | 0.19 |
| High alternate | 0.90 |
| Severe alternate | 1 |

**Table 2. Modified Alternate Bearing Index (MABI) of some important cultivars of apple (Atay et al., 2013)**

| Cultivar | MABI |
|---|---|
| Jonagold | 0.42 |
| Rajka | 0.65 |
| Topaz | 0.33 |
| Clear Red | 0.49 |
| Redchief Delicious | 0.57 |
| Starkrimson Delicious | 0.45 |
| Starkspur Golden Delicious | 0.51 |
| Golden Delicious | 0.71 |
| Golden Reinders | 0.78 |
| Granny Smith | 0.35 |
| Braeburn | 0.20 |
| Fuji | 0.56 |

**Table 3. Alternate bearing index of some important rootstocks of pistachio [17]**

| Rootstocks | Alternate bearing index |
|---|---|
| Kerman | 0.33 |
| Golden Hills | 0.22 |
| Lost Hills | 0.14 |
| B5-8 | 0.89 |
| B19-1 | 0.79 |

## 3. CAUSES OF ALTERNATE BEARING

Impact of intrinsic and exogenous factors are observed on bearing habit of various tropical and subtropical fruit crops. Vegetative and flower bud formation in tropics and subtropics varies for same fruit species, and implicates age of shoot and cool inductive temperatures programmed by the coincidence of internal and environmental signals in higher plants. In general, tropical trees are induced to flower by environmental signals. Besides these there are several endogenous and exogenous factors responsible for this rhythm. Exogenous factors can be classified into: Environmental (Temperature, Atmospheric humidity, Rains, Edaphic stress and Spring frost) and Biotic (Insect pest and Diseases), Endogenous factors consist effect of genotype, rootstock, leaves & flowering habit, tree age and vigour, pollination on fruit-set, effect of seeds and growing fruit on flower inhibition, competition between vegetative and reproductive sinks, effect of carbon: nitrogen ratio, hormonal imbalance, natural abscission of buds, flowers and fruits, crop overload flower inhibition by growing fruits, nutrient status and others. Few are discussed below for a comprehensive understanding:

## 3.1 Exogenous Factors

### 3.1.1 Environmental factors

“Occurrence of very low or high temperature at the time of flowering, fruit set or after fruit set may trigger alternate bearing behavior in fruit plant. Low temperature can directly kill the floral parts, thereby affecting the fruit set e.g. Valencia oranges in Australia. High or low temperature may also interfere with the pollen-carrying insect, particularly bees, flies and wasps, as they don't take flight under very low or high temperature, which results in poor pollination and thereby in poor fruit-set. Extremely low or high air humidity may affect yield through poor pollen germination owing to drying or desiccation of stigmatic fluid result poor fruit-set and excessive drop of the flower e.g. avocado, olive, oranges, grapefruits *etc*. Unwanted showers of rain or drought during flowering, convert 'on' year into an 'off' year directly or indirectly. Cloudy weather and rains during blooming period reduce the yield in mango directly by creating favorable conditions for the diseases like, powdery mildew and anthracnose *etc*. Spring frost is most limiting climatic factor in temperate regions which destroys the flowers, particularly in susceptible cultivars of apple, pear, pecans and other stone fruits. Synchronization of alternation over wide areas often has been blamed on spring frost with apples, olives (Morettini, 1950), pecans [18], and mangos in cool areas” [19].

### 3.1.2 Biotic factors

It results poor bud initiation in the current year and heavy flowering in the following year. Numerous insect-pest and disease attack fruit plants. They may attack foliage, flower, young and mature fruits. Pest like hoppers in mango, black aphid in pecans and mites in apples may cause alternation of the entire area. Powdery mildew of mango, pre-mature defoliation of apple, walnut, scab of apples *etc*. are the most dreaded diseases and may convert a fruitful 'on' year into 'off' year. Soil conditions, which are conducive to low root activity, are detrimental to plant health, causing to produce low yield. Excess of salts in the soil may lead to scorching of leaves and premature leaf fall, which indirectly reduces reserve food. Soil moisture stress during growth or flowering is conducive to leaf and fruit abscission in olive, mango etc. Drought may have an effect on alternation because it favours excessive drop of reproductive organs, leaves and developing fruit.

## 3.2 Effect of Genotype

Genetic control regulates the bearing behavior in both regular and alternate bearing type in different Family, genera and species of fruits. In citrus *miR156* regulator controls homologous SPL (squamosa promoter binding-like) in “Off year” (Shalom *et al*., 2015) at University of California, Davis. Some cultivars within a species bear regularly, whereas others are alternate bearer. Cultivars are regular in one location, but behave as an alternate bearer in other location. Rootstocks are directly involved in the process of deciding the bearing behaviour. In general, weak or dwarfing rootstock reduce biennial problem. e.g. apple, citrus *etc*. Kallsen et al. [27] studied effect of different genotypes of pistachio nut in the intensity of alternate bearing at California.

**Table 4. Environmental attributes associated with flowering in various fruit crops**

| Fruit Crop | Critical weather parameters for flowering | References |
|---|---|---|
| Apple | Most of apple varieties required 1000-1600 chilling hours during winter to break the rest period, however some low chill varieties require only 500-800 chilling hours. The average summer temperature should be around 21-24 °C during active growth period, Shading 30% to 70% | [20] |
| Peach | Chilling requirement is necessary for flower induction | [21] |
| Avocado | Period of low Temperature around 150 /100, 180 /15 0 C | [22] |
| Litchi | Temperature around 10 °C, low temperature induces flowering | [23] |
| Mango | Temperature below 15-20 °C, with florally inductive temperatures varying between cultivars. Cool temperature is the dominant induction factor under subtropical conditions but under tropical conditions it may be brief, erratic or non-existent in some season. | [24,25,26] |

## 3.3 Endogenous Factors

### 3.3.1 Effect of leaves & flowering habit

Production of sufficient photosynthetic products and different endogenous growth regulators by leaves are pre-requisite for flower initiation. Fruit set and development of fruit are better, when fruits are borne on mixed (leafy) inflorescence, because of higher auxin's activity e.g. citrus. Fruit plants producing flower buds terminally tend to alternate bearing more in comparison to those producing flower buds laterally e.g., mango, litchi *etc*.

### 3.3.2 Effect of tree age and vigour

The effects of tree age or vigour on the bearing behaviour of fruits are unclear and sometimes not even uniform with the same cultivar at different locations. In general, alternate bearing becomes more pronounced with the increasing age of bearing trees, e.g., apple, mango, pecan, and pistachio nut. But in citrus, plants in the juvenile phase tend to alternate more than in later years of age [28].

### 3.3.3 Effect of pollination on fruit-set

Lack of suitable pollinator-pollinizer varieties causes poor yield in date palm, mango, avocado, and various self-incompatible mandarins, etc. Pollination is the most limiting factor in avocado due to the existence of PDSD (protogynous, diurnally synchronous dichogamy) [30].

### 3.3.4 Effect of seeds and growing fruit on flower inhibition

Seeds within the developing fruits exert strong inhibitory influence on flower bud production e.g. apple. Regular bearing cultivars have self-thinning capacity by which they maintain load year-after-year. e.g. oranges, grapefruits, plum *etc*. Auxins produced by the seeds within a fruit, moves into the fruiting spur. This movement is stronger in alternate bearers (Laxton's Superb) then regular bearers (Cox Orange Pippin) variety of apple. Auxins maintained at low concentration in spurs, which initiate flowering process during "off" year mainly by greater translocation of phloridizin from leaves [31].

### 3.3.5 Carbon / nitrogen ratio

In fruit plants, carbon and nitrogen reserves play important role in flower bud initiation, but these don't from the primary cause of alternate bearing in fruit plants. However, create favorable condition for the synthesis and action of the substance responsible for flowering [31]. "Mango exhibits consistently greater production of total sugars and reducing sugars, with peak availability during bud burst in apical buds, as a result of the paclobutrazol-induced enhancement in C: N ratio" (Upreti et al., 2014).

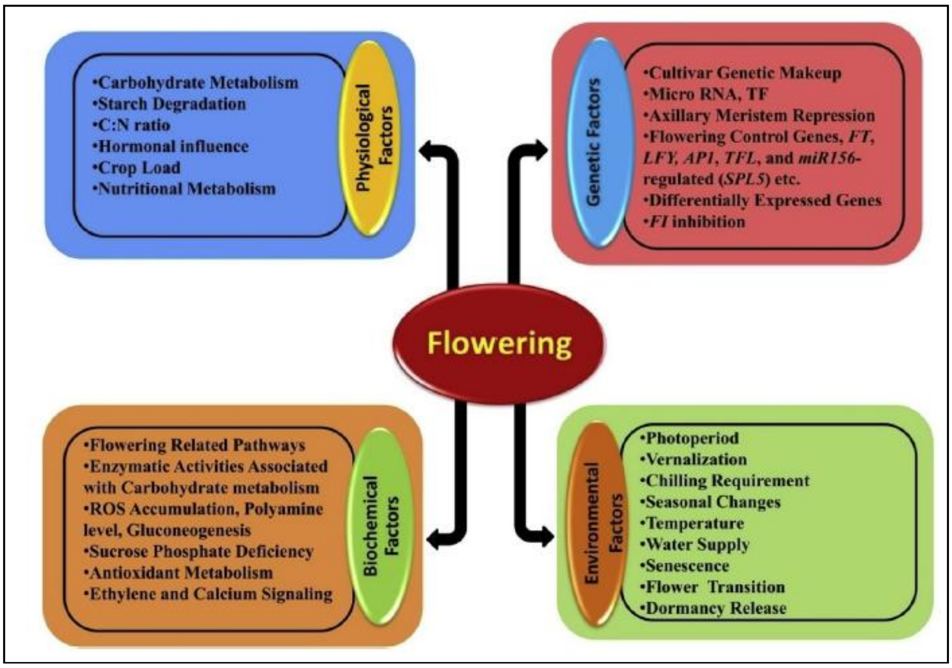


**Fig. 1. Effect of various factors on flowering habit of fruit crops [29]**

### 3.3.6 Hormonal imbalance

"Flowering time is largely affected by large chemical constituents such as plant hormones [32,33]. Biennial bearing problem appears to be closely associated with the fruit development process and the inhibitory influence of the developing fruits on vegetative growth. Higher levels of auxin like substances and an inhibitor (similar to ABA) and lower levels of Gibberellin ($GA_3$) like substances are vital for a florigenous shoot. There is inverse relationship between the level of endogenous inhibitor in the shoot and vegetative growth. Higher inhibitor content promotes flowering".

*3.3.6.1 Auxin*

The role of auxin is inhibiting flowering after an "on" year crop. This mechanism is essentially based on the ATA theory. The presence of auxin, which functions as a mobile signal, may be responsible for GA synthesis in the meristem, demonstrating that both GA and auxin act as FI-inhibiting signals [34]. Gibberellin is the primary messenger that causes the second messenger, auxin, to synthesize and transport. Polar auxin transport via a dominating sink is linked to fruit thinning from "on" year trees, triggering return bloom. It works as a potential mobile signal, which influences flowering [29].

*3.3.6.2 Gibberellins*

"Gibberellins (GA) suppress flowering in several perennial fruit crops" (Bangerth, 2009; Goldberg-Moeller *et al*., 2013). "However, it has been observed that GA4 promotes apple flowering during 'Off' years. Indeed, the use of GA7 had the greatest inhibitory effect on apple flower induction" (Tromp, 1982). "Common horticultural approaches and management, such as the external application of GA during 'Off' years to prevent an excessive FI, delayed the biennial bearing cycle. Bioactive GAs is thought to have an inhibitory effect on core flowering genes and pathways in apples. Thus, high GA3 levels suppress floral induction, but other growth regulators such as GA4, ABA, and cytokinins stimulate flower induction in olive" [35].

*3.3.6.3 Abscisic acid*

Because of the stress imposed by fruit overload, the level of abscisic acid (ABA) and its isomer, t-ABA was higher in 'On' crop trees than in 'Off' crop trees. The use of ABA suppressed bud sprouting and profuse flowering in Citrus unshiu (Garcia-Luis *et al*., 1986). On the contrary, it has been observed that flowering stimulates ABA activity. As a result, elevated ABA levels have been seen in the leaves of 'Off' crop trees and during de-fruiting of 'On' crop trees [29].

### 3.3.7 Crop overload

Higher fruit number creates a cumulative sink, depletion of reserve food material during 'on' year because of overload may even cause tree to collapse. Fruit overload may also alter the hormonal balance of the tree that may affect future morphogenetic. "Moderate blossoming is one of the chief conditions of annual fruit bearing in fruit trees. Fruiting is an exhausting process and the number of fruits retained till harvest is a varietal feature. The total number of fruits that are harvested is important because of their deleterious influence on the production of new shoots for the next season and their subsequent fruit-bud differentiation. Therefore, the fruit load appears to be one of the main conditioning factors for 'on' or 'off' year in fruit crops. This hypothesizes, that if fruit load is more, then it blocks the recognition of flowering inductive signal (s). It prevents the emergence of inflorescence and bud break" [36,37].

### 3.3.8 Molecular approaches

*3.3.8.1 Flowering genes*

In Arabidopsis, *BFT* works similarly to *TFL1* and inhibits floral meristem growth. *SOC1* increased FI in response to GAs (GA4) in annual plants [38]. Similarly, *CO* modulates the expression of two floral integrators, *LFY* and *SOC1*, in Arabidopsis via *FT* [39]. In perennial fruit crops, studies on flowering time-linked genes are limited due to their long gestation cycle [40]. Previous research on flowering linked genes and gene expression studies at various stages of the flowering phenophase in perennial fruit crops allows for the identification of targeted genes and the understanding of their relationships with reproductive processes [61,62]. These include the flowering promoter gene, which produces a protein that is a critical regulator of florigen, as well as floral meristem identity determinant genes such as the leafy (LFY) and apetala1 (AP1) genes [29]. Flowering locus c (FLC), terminal flower 1 (TFL1), brother of ft (BFT), and short vegetative phase (SVP) are other important genes that function as repressors in the floral pathway. Flowering locus c (FLC) is a key repressor gene that efficiently controls flowering timing [38].

*3.3.8.2 Transcriptome approach*

To understand the "On" and "Off" mechanisms functioning in perennial fruit trees, gene regulation studies at the transcriptional and post-translational levels are required throughout the vegetative to blooming and fruiting transitions [41]. In order to understand the bearing tendencies of perennial fruit crops, an RNA profile is for both types of mRNAs and short regulatory RNAs is required [42]. Using microarray and RNA sequencing to identify differentially expressed genes (DEGs), researchers may be able to unravel the complicated mechanisms that change 'On' buds to 'Off' buds [2]. The importance of interpreting gene expression data is emphasized in order to identify those genes whose expression patterns are associated with a specific trait of interest. MicroRNA (miRNA) plays a critical regulatory role in a variety of physiological processes. Previously, miR156 was discovered to be involved in the regulation of blooming time [43].

“Differential gene expression studies were conducted in many fruit crops, for example, in mango leaves, a few genes, FT, AP1, and LFY, were shown to be up-regulated during the flower induction period. In general, the expression of flower control genes in mango is induced in the leaves, buds, and stems in time for the beginning of the flower induction period (November-December) in regular bearing varieties, and in alternate bearers during the 'Off' crop year” [44,45].

## 4. CONTROL MEASURES OF ALTERNATE BEARING

### 4.1 Proper up Keep of Orchards

Proper maintenance of orchard helps in reducing the erratic bearing but cannot induce regularity of bearing among alternate bearing cultivars. Use of regular plough, recommended rate of manuring, assured irrigation after fruit set.

### 4.2 Use of Chemicals/ PGRs

Different chemicals has been reported more economical and effective for inducing regular flowering in fruit crops to reduce alternation problems, e.g., Morphactins, Ethephon, $NH_4$ Ions, Cytokinins, $KNO_3$, Maleic Hydrazide (MH), Cycocel. “Gibberellic Acid biosynthesis and increased cytokinin level, chlorophyll content improves mineral uptake and carbohydrate gradient of the entire plant system. This helps in achieving a balance in C: N ratio which induces flowering normally. The field should be irrigated immediately after treatment to increase efficiency. Effect of PBZ application to enhance and regulate flowering in mango field is well documented. Deblossoming of the panicles with NAA @ 200ppm during ‘on’ year, NAA has been used with success on mandarin-type fruits” [46]. Effect of ethephon and 2,4,5-T on number of fruits per plant and alternate bearing of Imperial Mandarin was studied by Zeftawi [47] at Australia. Hamdy, [48] observed effect of GA3 and NAA on fruit yield and alternate bearing index of Washington Navel orange at Egypt and suggested due to optimum level of GA3 act synergistically with auxin concentration to produce better reproductive growth during next year.

### 4.3 Use of Rootstocks

Effects of clonal rootstocks on Hass avocado on alternate bearing has been elucidated by Mickelbart et al. [49]. Effect of rootstock on apple tree bearing stability in cooler climate was observed by Kviklys et al. [50]. Similarly, Response of mango varieties at different height of grafting on rootstock was studied by Pandey [26].

### 4.4 Planting of Fairly Regular Bearing Varieties

It is most suitable and desirable alternative to overcome the problem of alternate bearing.

### 4.5 Pruning

Removing bearing surface (fruit buds) stimulates vegetative growth from remaining buds. Pruning is adopted to maintain a proper physiological balance between growth and fruiting. It is helpful to getting regular crops in mango, grapefruit, mandarin and Valencia orange etc. Uddin et al. [51] studied on effect of post-harvest pruning on fruit yield and alternate bearing index of mango they found maximum fruit yield with Severe pruning (30 cm down from the apex) compare to control. Effect of pruning and paclobutrazol on number of fruits and fruit yield in three mango cultivars Raspuri, Dashehari and Amrapali highest number of fruits and fruit yields observed with pruning of current season’s growth and soil application of PBZ @ 3 ml/m canopy diameter in Raspuri cultivar [52]. Maximum fruit yield of mango cv. Dashehari observed with 10 cm heading back of terminal shoots annually immediately after fruit harvest at Pantnagar [53] and at Lucknow [54].

**Table 5. Effect of paclobutrazol on flowering and fruiting of various fruit crops**

| Crops | PBZ concentration | Method of application | Mode of action | References |
|---|---|---|---|---|
| Mango | 1.0 g a.i./ m canopy | Soil application | Growth reduction, flower induction, increased sex ratio | Burondkar and Gunjate (1993) |
| | 20-40 g/tree | | Increase flowering and fruiting | [58] |
| Litchi | 5 g / m plant canopy | Soil application | Enhanced flowering and yield | [59] |
| Mandarin | 1.0 to 2.0 g a. i./ plant | Foliar spray | Flower induction | Dos Santos *et al.* (2004) |
| Avocado | 1% | Foliar application | Yield enhancement | [60] |

**Table 6. Desirable regular bearing cultivars of various fruit crops**

| Sr. No. | Fruit crops | Regular bearing cultivars |
|---|---|---|
| 1. | Mango | Rumani, Amrapali, Mallika, Arka Aruna, Arka Puneet, Ratna, Dashehari-51, Pusa Surya |
| 2. | Apple | Spur type varieties e.g., Oregon Spur, Golden Spur, Wellspur *etc* |
| 3. | Citrus | Pineapple, Jaffa, Malta Blood Red, *etc.* in Sweet orange<br>In Mandarin, Coorg, Khasi *etc*. |
| 4. | Avocado | Fuerte, Hass *etc*. |

### 4.6 Thinning of Fruits

Removal of extra fruits to reduce the crop load during the "on" year, so as to get some fruits in successive year. Thinning promotes the development of large size, high quality fruit set at harvest stage and prevents the limb breakage of trees heavily loaded with fruits. By managing the above cultural operations irregular bearing can be managed in fruit crops.

### 4.7 Girdling

The process of girdling in citrus in autumn increases the flowering next spring, while when it is done at blossom time, it increases the set. Similar practices are also used with 'Nabal' avocado, where inducing alternation on half of the tree proves commercially beneficial.

### 4.8 Smudging

Practices of smudging to induce flowering in mango has been reported from Philippines in the year 1923 [55].

### 4.9 Early Harvesting

"It was shown that removal of fruits from 'On' year crop enhanced the return bloom [56]. Similar techniques have been used with mango and apples" [57].

## 5. CONCLUSION

Alternate bearing is a major economic problem in fruit crops. North Indian varieties are showing alternate bearing, whereas south Indian varieties are regular bearing. The endogenous factors are mainly responsible for alternate bearing in fruit crops. Paclobutrazol is a promising and widely used chemical to management of alternate bearing. The application of paclobutrazol @ 5g - 10g/tree during September-October play an important role in early and profuse flowering and giving more annual yield without affecting fruit size and quality. This application can use effectively in various crops like mango, litchi, olive, avocado etc.

## 6. FUTURE PROSPECTS

Alternate bearing is a complex problem in fruit crops. Till date exact causes factor of alternate bearing is not known that needs an attention on to know the exact causing factor. There is also lack of regular bearing along with good fruit quality cultivars in most of the fruit, need to focus on developing regular bearer with good fruit quality cultivars. And also need to pay attention on developing suitable and compatible rootstocks. Can also be made study on alternate bearing at gene level. There is also lack of proper control measure of alternate bearing in all the fruit crops which needs an attention on its standardization.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES


1. Goldschmidt EE. The evolution of fruit tree productivity: A review. Economic Botany. 2013;67:51–62.
2. Sharma N, Singh SK, Singh NK, Srivastav M, Singh BP, Mahato AK, Singh JP. Differential gene expression studies: A possible way to understand bearing habit in fruit crops. Transcriptomics Open Access. 2015;3(110):10–12.
3. Singh RN. Biennial bearing in fruit trees; accent on mango and apple. Indian Council of Agricultural Research, Bul. 1971;30.
4. Jonkers H. Biennial bearing in apple and pear: A literature survey. Scientia Horticulturae. 1979;11:303–317.
5. Chandler WH. Evergreen orchards. Henry Kimpton, London; 1950.
6. Crane JC, Nelson MM. The unusual mechanism of alternate bearing in pistachio. HortScience. 1971;6:489-490.
7. Fisher DV. Time of blossom bud induction in apricots. Proc. Amer. Soc. Hart. Sci. 1951;58:19-22.
8. Jones WW, Embleton TW, COGGINS CW. Jr. Starch content of roots of 'Kinnow' mandarin trees bearing fruits in alternate years. HortScience. 1975;10:514.
9. West ES, Barnard C. The alternation of heavy and light crops in the 'Valencia' late orange. J. Counc. Sci. Ind. Res. Australia. 1935;10:215-224.
10. Worley RE. Effects of defoliation date on yield, quality, nutlet set and foliage regrowth for pecan. Hort Scicnce. 1971;6:446-447.
11. Barritt BH, Konishi BS, Dilley MA. Tree size, yield and biennial bearing relationships with 40 apple rootstocks and three scion cultivars. Acta Horticulturae. 1997;451:105–112.
12. Reddy YTN, Kurian RM, Ramachander PR, Singh G, Kohli RR. Long-term effects of rootstocks on growth and fruit yielding patterns of ‘Alphonso’ mango (*Mangifera indica* L.). Scientia Horticulturae. 2003;97(2):95-108.
13. Cilas C, Montagnon C, BarHen A. Yield stability in clones of *Coffea canephora* in the short and medium term: Longitudinal data analyses and measures of stability over time. Tree Genetics and Genomes. 2011;7(2):421-429.
14. Smith MW, Shaw RG, Chapman JC, Owen-Turner J, Lee LS, McRae KB, Jorgensen KR, Mungomery WV. Long-term performance of ‘Ellendale’mandarin on seven commercial rootstocks in sub-tropical Australia. Scientia Horticulturae. 2004;102(1):75-89.
15. Wood BW, Stahmann D. Hedge pruning pecan. Hort Technology. 2004;14(1):63-72.
16. Rosenstock TS, Rosa UA, Plant RE, Brown PH. A reevaluation of alternate bearing in pistachio. Scientia Horticulturae. 2010;124(2):149-152.
17. Kallsen CE, Parfitt DE, Holtz B. Early differences in the intensity of alternate bearing among selected pistachio genotypes. HortScience. 2007;42(7):1740-1743.
18. Sparks D. The alternate fruit bearing problem in pecans. 65th Annual Report of the Northern Nut Growers Association. 1974:145-157.
19. Singh RN, Majumder PK, Sharma GC, Sinha, Bose PC. Effect of deblossoming on the productivity of mango. Scientia Horticulturae. 1974;2:399–403.
20. Wilkie JD, Sedgley M, Olesen T. Regulation of floral initiation in horticultural trees. Journal of Experimental Botany. 2008;59(12):3215-3228.
21. Scorza R. Sherman WB. Peaches In: Janick J, Moore JN. (Eds.) Fruit breeding, vol 1: Tree and tropical fruits. John Wiley and Sons, New York. 1996:325–440.
22. Wakabayashi K, Huber DJ. Purification and catalytic properties of polygalacturonase isoforms from ripe avocado (*Persea americana*) fruit mesocarp. Physiologia Plantarum. 2001;113(2):210-216.
23. Menzel C. The control of floral initiation in lychee: A review. Scientia Horticulturae. 1983;21(3):201-215.
24. Núñez-Elisea R, Davenport TL. Flowering of mango trees in containers as influenced by seasonal temperature and water stress. Scientia Horticulturae. 1994;58(1-2):57-66.
25. Whiley AW, Rasmussen TS, Wolstenholme BN, Saranah JB, Cull BW. Interpretation of growth responses of some mango cultivars grown under controlled temperatures. In III International Mango Symposium. 1989;291:22-31.

26. Pandey RM. Physiology of flowering in mango. Acta Horticulturae. 1989;213:361–380.
27. Kallsen CE, Parfitt DE, Holtz B. Early differences in the intensity of alternate bearing among selected pistachio genotypes. HortScience. 2007;42(7):1740-1743.
28. Hoblyn TN, Grubb NH, Painter AC, Wates BL. Studies in Biennial Bearing.—I. Journal of Pomology and Horticultural Science. 1937;14(1):39-76.
29. Sharma N, Singh SK, Mahato AK, Ravishankar H, Dubey AK, Singh NK. Physiological and molecular basis of alternate bearing in perennial fruit crops. Scientia Horticulturae. 2019;243:214-225.
30. Gazit S. Pollination and fruit set of avocado. Proc., First Int. Trop. Fruit Short Course: the Avocado, Univ. of Florida, Gainesville FL. 1977:88-92.
31. Kumar A, Bhuj BD, Singh CP. Alternate bearing in fruits trees: A review. Int. J. Curr. Microbiol. App. Sci. 2021;10(01):1218-1235.
32. Davis SJ. Integrating hormones into the floral-transition pathway of *Arabidopsis thaliana*. Plant Cell and Environment. 2009;32:1201–1210.
33. Domagalska MA, Sarnowska E, Nagy F, Davis SJ. Genetic analyses of interactions among gibberellin, abscisic acid, and brassinosteroids in the control of flowering time in *Arabidopsis thaliana*. PLoS One. 2010;5.
34. Bangerth F. Flower induction in perennial fruit trees: still an enigma. Acta Hortic. 2006;727:177–195.
35. Baktir I, Ulger S, Kaynak L, Himelrick DG. Relationship of seasonal changes in endogenous plant hormones and alternate bearing of olive trees. Hort. Science. 2004;39(5):987–990.
36. Albrigo LG, Saúco VG. Flower bud induction, flowering and fruit-set of some tropical and subtropical fruit tree crops with special reference to citrus. Acta Horticulturae. 2004;632:81–90.
37. Verreynne JS, Lovatt CJ. The effect of crop load on budbreak influences return bloom in alternate bearing “Pixie” mandarin. Journal of the American Society for Horticultural Science. 2009;134:299–307.
38. Yoo SJ, Chung KS, Jung SH, Yoo SY, Lee JS, Ahn JH. Brother of FT and TFL1 (BFT) has TFL1-like activity and functions redundantly with TFL1 in inflorescence meristem development in Arabidopsis. Plant J. 2010;63:241–253.
39. Parcy F, Flowering: a time for integration. Int. J. Dev. Biol. 2005;49:585–593.
40. Abbott AG, Zhebentyayeva T, Barakat A, Liu Z. The genetic control of budbreak in trees. Adv. Bot. Res. 2015;74:201–228.
41. Khan MR, Ai XY, Zhang JZ. Genetic regulation of flowering time in annual and perennial plants. Wiley Interdiscip. Rev. RNA. 2014;5:347–359.
42. Yanik H, Turktas M, Dundar E, Hernandez P, Dorado G, Unver T. Genomewide identification of alternate bearing-associated microRNAs (miRNAs) in olive (*Olea europaea* L.). BMC Plant Biol. 2013;13(10).
43. Wang JW. Regulation of flowering time by the miR156-mediated age pathway. J. Exp. Bot. 2014;65:4723–4730.
44. Nishikawa F, Endo T, Shimada T, Fujii H, Shimizu T, Omura M, Ikoma Y. Increased CiFT abundance in the stem correlates with floral induction by low temperature in Satsuma mandarin (*Citrus unshiu* Marc.). J. Exp. Bot. 2007;58:3915–3927.
45. Shalom L, Samuels S, Zur N, Shlizerman L, Zemach H, Weissberg M, Ophir R, Blumwald E, Sadka A. Alternate bearing in citrus: changes in the expression of flowering control genes and in global gene expression in on versus off crop trees. PLoS One. 2012;7(10):46930.
46. Galliani S, Monselise SP, Goren R. Improving fruit size and breaking alternate bearing in ‘Wilking’ mandarin by ethephon and other agents. HortScience. 1975;10:68-69.
47. El-Zeftawi BM. Effects of ethephon and 2,4,5-T on fruit size, rind pigments and alternate bearing of ‘Imperial’ mandarin. Scientia Horticulturae. 1976;5(4):315-320.
48. Hamdy AE. Effect of GA3 and NAA on growth, yield and fruit quality of Washington navel orange. Egyptian Journal of Horticulture. 2017;44(1):33-43.
49. Mickelbart MV, Bender GS, Witney GW, Adams C, Arpaia ML. Effects of clonal rootstocks on “Hass” avocado yield components, alternate bearing, and nutrition. Journal of Horticulture Science and Biotechnology. 2007;82(3):460–466.
50. Kviklys D, Čeidaitė A, Lanauskas J, Uselis N, Samuolienė G. The effect of rootstock on apple tree bearing stability in a cooler

climate. Agricultural and Food Science. 2016;25(1):81-88.

51. Uddin MS, Hossain MF, Islam MS, Hossain MM, Uddin MS. Effect of post-harvest pruning on the control of tree size and yield of mango. Bulletin of Institute of Tropical Agriculture. 2014;37:41–6.
52. Srilatha V, et al. Pruning and paclobutrazol induced changes on fruit yield and fruit quality in mango (*Mangifera indica* L.). Andhra Pradesh J Agril. Sci. 2015;1(4):50-57.
53. Singh AK, Singh CP, Bora L. Impact of pruning on growth, yield and quality of mango cv. Dashehari. Journal of Horticultural Sciences. 2017;12(2):118-123.
54. Barman P, Mishra D. Tip pruning for synchronized vegetative growth and controlling alternate bearing in mango (*Mangifera indica*). Indian Journal of Agricultural Sciences. 2018;88(4):101-107.
55. Sen PK, Mallik PC. Effect of smudging on Mango. Indian Journal of Horticulture. 1947;5(1&2):29-34.
56. Shalom L, Samuels S, Zur N, Shlizerman L, Doron-Faigenboim A, Blumwald E, Sadka A. Fruit load induces changes in global gene expression and in abscisic acid (ABA) and Indole Acetic Acid (IAA) homeostasis in citrus buds. Journal of Experimental Botany. 2014;65:3029–3044.
57. Moss GI, Bevington KB. Gallasch PT, Zeftawi BM, Bacon P, Thornton IR, Freeman B. Methods to control alternate cropping of Valencia orange trees in Australia. Proceedings of the International Society for Citriculture. 1977;2:704-708.
58. Singh Z. Effect of (2RS, 3RS) paclobutrazol on tree vigour, flowering, fruit set and yield in mango. In International Conference on Integrated Fruit Production. 1998;525:459-462.
59. Faizan A, Mohammad A, Ganesh K. Effect of paclobutrazol on growth, yield and quality of litchi (*Litchi chinensis* Sonn.). Indian J. Hort. 2000;57(4):291–294.
60. Adato I. Effects of paclobutrazol on avocado (*Persea americana* Mill.) cv.'Fuerte'. Scientia Horticulturae. 1990;45(1-2):105-115.
61. Burondkar MM, Gunjate RT, Magdum MB, Govekar MA. Rejuvenation of old and overcrowded Alphonso mango orchard with pruning and use of paclobutrazol. In VI International Symposium on Mango. 1999;509:681-686.
62. Couranjou J. Research on the genetic causes of the alternation of the domestic plum tree (*Prunus domestica* L.) II. Effect of fruit load in one part of the tree on flower induction in the rest of the fruitless tree; level of autonomy between the two parties according to the cultivars. Physiol. Veg. 1978;16:505-520.



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