Review Article

Alternate Bearing in Fruit Crops: Causes and Control Measures

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. Among various indices that have been used for quantifying AB, number of flowering shoots in a canopy fined direct corroboration to fruit yield assessments in recurring years. Based on the alternate bearing index, it is divided in four groups viz., no alternation, less alternate, high alternate, complete alternation. 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.

Keywords: Alternate bearing, fruit crops, exogenous factors, endogenous factors, control measures

I. 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 (Goldschmidt, 2013; Sharma *et al.*, 2015). It is found in most of fruit crops like *Olea europea* (Morettini 1950), *Mangifera indica* (Singh 1971), *Malus x domestica* (Jonkers, 1979), *Litchi chinensis* (Chandler, 1950), *Pistacia vera* (Crane & Nelson, 1971), *Persea americana* (Chandler, 1950), *Prunus armeniaca* (Fisher, 1951), *Citrus reticulata,* (Jones *et al.*, 1975), *Citrus sinensis* (West & Barnard, 1935), *Pyrus communi* (Jonkers, 1979), *Carya illinoensis* (Worley, 1971), *Prunus domestica* (Courajou, 1978) and *Phoenix dactylifer.*

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.

II. ALTERNATE BEARING INDEX (ABI)

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

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

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
Complete alternation	1

The Biennial Bearing Index has been used in various fruit crops like in apple (Barritt *et al.*, 1997), mango (Reddy *et al.*, 2003), coffee (Cilas *et al.*, 2011), citrus (Smith *et al.*, 2004), pecan (Wood *et al.*, 2004), and pistachio (Rosenstock *et al.*, 2010). To assign the role of flowering in the phenomenon, the name was later changed to "Modified Alternate Bearing Index" (MABI).

III. 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:

1. Exogenous factors

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 (Sparks, 1974), and mangos in cool areas (Singh *et al.*, 1974).

Table No. 2: 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%	Wilkie *et al.*, 2008
Peach	Chilling requirement is necessary for flower induction	Scorza and Sherman, 1996
Avocado	Period of low Temperature around 150 /100, 180 /15 0 C	Wakabayashi and Huber, 2001
Litchi	Temperature around 10 °C, low temperature induces flowering	Menzel, 1983
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.	Nunez-Elisea and Davenport, 1994, Whiley *et al*., 1989, Pandey, 1989

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.

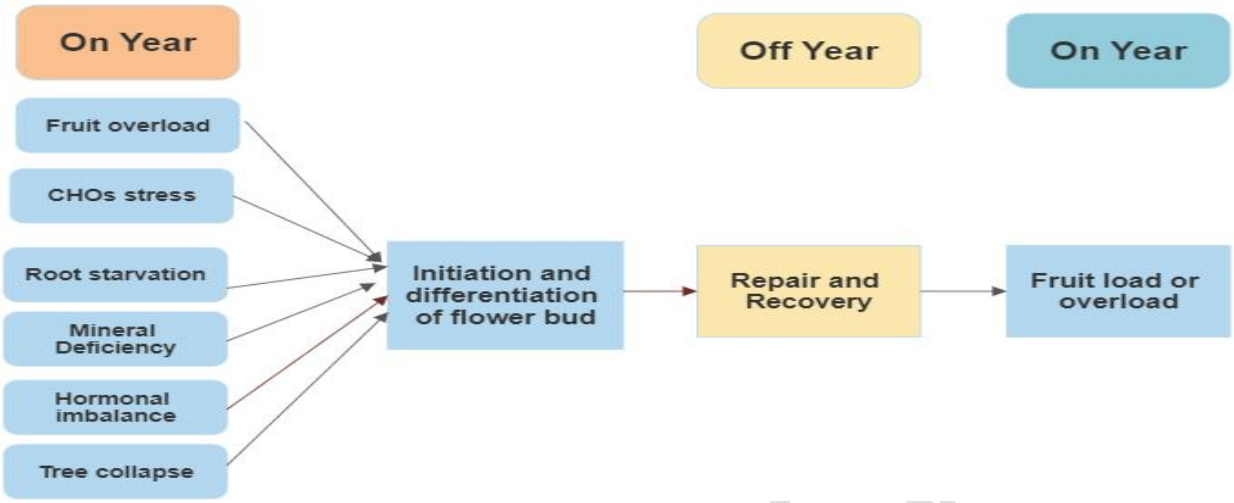
2.1. Effect of genotype

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.* (2007) studied effect of different genotypes of pistachio nut in the intensity of alternate bearing at California.

2. Endogenous Factors

2.2. 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*.

Fig 1: Diagrammatic representation of internal processes involved in alternate bearing

2.3. 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 (Hoblyn *et al.*, 1937).

2.4. 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) (Gazit, S., 1977)**.**

2.5. 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.

2.6. 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.

2.7. Hormonal imbalance

Flowering time is largely affected by large chemical constituents such as plant hormones (Davis, 2009; Domagalska *et al.*, 2010). 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.

2.8. 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 (Albrigo and Saúco, 2004; Verreynne and Lovatt, 2009).

IV. CONTROL MEASURES OF ALTERNATE BEARING

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.

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 (Galliani *et al.,* 1975). Effect of ethephon and 2,4,5-T on number of fruits per plant and alternate bearing of Imperial Mandarin was studied by (Zeftawi,1976) at Australia. Hamdy, (2017) observed effect of GA_3 and NAA on fruit yield and alternate bearing index of Washington Navel orange at Egypt and suggested due to optimum level of GA_3 act synergistically with auxin concentration to produce better reproductive growth during next year.

Table 3. 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	Singh (1998)
Litchi	5 g / m plant canopy	Soil application	Enhanced flowering and yield	Faizan *et al.* (2000)
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	Adato (1990)

3. Use of rootstocks

Effects of clonal rootstocks on Hass avocado on alternate bearing has been elucidated by (Mickelbart et al., 2007). Effect of rootstock on apple tree bearing stability in cooler climate was observed by (Kviklys *et al.* 2016). Similarly, Response of mango varieties at different height of grafting on rootstock was studied by (Pandey, 1989).

4. Planting of fairly regular bearing varieties

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

Table : 4 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 In Mandarin, Coorg, Khasi *etc*.
4.	Avocado	Furete, Hass *etc.*

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.* 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 (Srilatha *et al.* 2015). Maximum fruit yield of mango cv. Dashehari observed with 10 cm heading back of terminal shoots annually immediately after fruit harvest (Singh *et al.* 2017) at Pantnagar, (Barman & Mishra 2018) at Lucknow.

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.

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.

8. Smudging

Practices of smudging to induce flowering in mango has been reported from Philippines in the year 1923 (**Sen *et al.*, 1947)**.

9. Early harvesting

It was shown that removal of fruits from 'On' year crop enhanced the return bloom (Shalom *et al.*, 2014). Similar techniques have been used with mango and apples (Moss *et al*., 1977).

V. 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.

VI. 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.

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