Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 01 (JAN-FEB, 2026)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Physiological Basis of Alternate Bearing: A Focused Review

*Harapriya Das
M.Sc. Scholar, Department of fruit science and horticulture technology,
College of Agriculture, OUAT, Bhubaneswar, Odisha, India – 751003
*Corresponding Author's email: harapriyadas2000@gmail.com

Alternate bearing (AB), also known as biennial bearing, is a common reproductive pattern in many perennial fruit crops, where a heavy fruiting ("on-year") is followed by a year of low or negligible production ("off-year"). This cyclical behaviour affects yield stability, orchard productivity, and economic outcomes for growers around the world. The physiological basis of alternate bearing involves complex interactions among hormonal signals, carbohydrate dynamics, source–sink relationships, and gene expression patterns that influence flowering induction and reproductive development. This review synthesizes current scientific understanding of these physiological mechanisms, highlights key factors contributing to AB, and discusses implications for management and future research.

Keywords: Alternate bearing, biennial bearing, flowering induction, plant hormones, carbohydrate reserves, perennial fruit crops

Introduction

Alternate bearing (AB) is a pervasive phenomenon in many perennial fruit tree species such as mango, citrus, olive, apple, and pistachio, where a season of abundant fruit production is followed by a year of sparse or no fruiting. This irregular pattern creates economic and management challenges, as the fluctuating yields complicate harvest planning and market supply. Biennial or alternate bearing arises from physiological signals that alter the allocation of resources and regulation of flowering responses from one season to the next. According to pomological definitions, biennial bearing refers to the irregular crop load where heavy fruit production suppresses flowering in the following year, leading to alternating high ("on") and low ("off") yields. Potential causes include hormonal imbalances, carbohydrate depletion, and altered genetic regulation of key developmental pathways.

Physiological Mechanisms Underlying Alternate Bearing

Hormonal Regulation and Signalling

Plant hormones play crucial roles in determining whether shoot apical meristems adopt a reproductive (flowering) or vegetative fate. One of the most important hormones implicated in alternate bearing is auxin—specifically indole-3-acetic acid (IAA). In several fruit trees, developing fruits generate strong polar auxin transport toward the stem, which in turn increases auxin levels in buds and suppresses their transition to flowering. This effect has been observed in citrus and olive, where fruit presence facilitates auxin movement and inhibits flowering induction in the subsequent season. Fruit load also influences other hormones, particularly gibberellins (GAs), which in many species are produced in developing seeds and can inhibit flower bud differentiation. High GA levels in fruiting shoots correlate with reduced flowering initiation, contributing to the off-year effect. The interaction between auxin and gibberellins is complex: auxin can stimulate GA biosynthesis in some contexts, further reinforcing the suppression of flower induction during on-years.

Carbohydrate Dynamics and Resource Partitioning

Alternate bearing is closely tied to the availability and allocation of carbohydrate reserves within a tree. Heavy cropping years demand substantial photosynthates to support fruit growth, which depletes carbohydrate reserves in stems, roots, and leaves. In the subsequent season, reduced carbohydrate availability limits the tree's capacity to initiate and sustain flower development, resulting in an off-year. High fruit loads act as strong sinks for carbohydrates, diverting resources that might otherwise be used for flower initiation and bud differentiation. Research in mango and citrus shows that heavy fruit loads can deplete stored starch and other carbohydrate pools, leading to reduced floral induction in the following season.

Source–Sink Interactions

Alternate bearing reflects shifts in source–sink dynamics. "Sources" such as mature leaves produce photosynthates, while "sinks"—including developing fruits, vegetative shoots, and buds—compete for these resources. During on-years, the high sink strength of abundant fruits draws assimilates away from buds, reducing energy available for floral induction. As a result, fewer flower buds develop, setting the stage for a low-yield off-year. The balance of source–sink relationships also intersects with hormonal signaling: sugars themselves can act as signaling molecules that influence gene expression related to flowering, interacting with hormonal pathways to integrate metabolic status with developmental outcomes.

Gene Expression and Molecular Influences

Molecular studies have revealed that expression of flowering-related genes fluctuates with alternate bearing cycles. Key genes such as **FLOWERING LOCUS T (FT)**, **APETALA1 (AP1)**, and **TERMINAL FLOWER1 (TFL1)** are involved in floral induction and bud fate determination. In on-years, expression patterns associated with vegetative development and hormone signaling can suppress pathways promoting flowering. Conversely, off-years show reactivation of floral gene expression associated with improved carbohydrate status and reduced inhibitory hormonal signals. Next-generation sequencing studies in mango varieties have shown differences in gene expression related to hormone metabolism and carbohydrate transport between alternate bearing and regular-bearing genotypes. These findings highlight how genetic and transcriptomic pathways integrate physiological signals into developmental outcomes.

Factors Influencing Alternate Bearing

Genotypic Variation

Different cultivars and species exhibit varying susceptibility to alternate bearing. For example, some apple cultivars show strong on/off cycles, while others maintain more consistent yields. Genetic differences influence hormone production, bud sensitivity, carbohydrate storage capacity, and developmental thresholds for floral induction.

Environmental Inputs

External factors such as temperature, light conditions, and water availability modulate physiological processes linked to flowering. In subtropical fruit trees, chilling hours and heat accumulation critically influence flowering induction; heavy crop loads can interfere with environmental signal perception and bud competence.

Cultural Practices

Horticultural practices like pruning, thinning of fruits, and nutrient management can alter source–sink relationships and hormone balances, thereby mitigating alternate bearing. Crop load management through selective thinning reduces excessive sink strength during on-years, allowing more carbohydrate availability for bud development in the following season.

Implications for Orchard Management

Understanding the physiological basis of alternate bearing can help growers adopt targeted strategies to stabilize yields. Managing carbohydrate reserves through balanced fertilization and irrigation, combined with practices like fruit thinning and rootstock selection that influence hormone signaling and resource dynamics, can reduce the severity of alternate bearing cycles. Advanced techniques such as genetic selection for regular-bearing varieties and precision pruning tailored to modulate hormonal and carbohydrate responses are emerging areas of focus for researchers and practitioners alike.

Conclusion

Alternate bearing is a complex physiological phenomenon driven by interactions among hormonal signals, carbohydrate allocation, source–sink dynamics, and genetic and environmental factors. Plant hormones like auxin and gibberellins mediate reproductive suppression during heavy crop years, while depleted carbohydrate reserves and altered gene expression further constrain floral induction. A deeper understanding of these mechanisms offers promising avenues for orchard management practices and breeding strategies aimed at minimizing yield fluctuations in perennial fruit crops.

References

1. Carraro, P., et al. (2026). *A rootstock-centered perspective on the regulation of alternate bearing in fruit trees*. *Journal of Experimental Botany*.
2. Jangid, R., Kumar, A., Masu, M., Kanade, N., & Pant, R. (2023). Alternate bearing in fruit crops: Causes and control measures. *Asian Journal of Agricultural and Horticultural Research*, 10(1), 10–19.
3. Kumar, A., Bhuj, B. D., & Singh, C. P. (2021). Alternate bearing in fruit trees: A review. *International Journal of Current Microbiology and Applied Sciences*, 10(01), 1218–1235.
4. Monselise, S. P., & Goldschmidt, E. E. (1982). *Alternate bearing in fruit trees*. Horticultural Reviews.
5. Sharma, N., et al. (2019). *Physiological and molecular basis of alternate bearing in perennial fruit crops*. *Scientia Horticulturae*, 243, 214–225.
6. Biennial bearing. (n.d.). In *Wikipedia*. Retrieved 2025, from https://en.wikipedia.org/wiki/Biennial_bearing