Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 02 (MAR-APR, 2026)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Phytohormonal Control of Fruit Set and Parthenocarpic Development

Arumugam Tamilselvan, Kousalya S, Durga Lakshmi Y, R Ramesh, Arul Selvam K A, Pradeep Krishnamurthy and *Kalieswari
Indian Agricultural Research Institute, New Delhi-110012, India
*Corresponding Author's email: 1999kalies@gmail.com

Fruit set is initiated following the release of pollen from the anthers, its deposition on the receptive stigma, subsequent pollen tube growth toward the ovules, and fertilization of the egg cells. Following fertilization, the petals abscise, and the ovary begins to swell. The fertilized ovules develop into seeds, which in turn stimulate the growth of the surrounding pericarp tissues, resulting in fruit formation. The final morphology of the fruit is determined by the number and type of floral organs involved, their spatial arrangement, and the patterns of growth and differentiation exhibited by the various tissues.

Fruit Set in Grapes

The process of fruit set in grapes progresses from flowering, where the calyptra (cap) is shed, to anthesis, and subsequently to the formation and development of berries.

Fruit Development Stages

Following pollination, the flower transitions into a fruit, while the fertilized ovules develop into seeds. Fruit development can be delineated into distinct phases: cell division, which commences after bloom and is characterized by active mitotic activity, with the duration typically shorter in smaller-fruited species and capable of being prolonged to some extent through blossom thinning practices; pit hardening in stone fruits, which involves the lignification of the endocarp; cell enlargement, which predominates during the later stages of fruit development and follows pit hardening in stone fruits; and fruit maturation, the final stage encompassing the last weeks or days prior to harvest. In mango, the progression of fruit development follows a similar pattern of growth and differentiation stages. Growth regulation forms the foundation for achieving regular and high-quality yields in fruit crops. The primary objective of crop regulation practices is to induce a period of rest in the tree, thereby promoting profuse blossom and fruit production during a designated flush. The underlying principle involves manipulating the natural flowering and fruiting cycles to align with a desired season. This approach aims to ensure uniformity, enhance fruit quality, maximize grower profitability, and reduce cultivation costs by preventing the occurrence of light, continuous cropping cycles.

Methods of Crop Regulation

Physical methods of crop regulation include shoot pruning, root exposure and pruning, shoot bending, withholding irrigation, manual thinning, and various cultural practices. Chemical methods involve the application of chemicals, plant growth regulators, chemical thinners, and nutrient solutions.

Role of Plant Growth Regulators in Fruit Set and Development

Plant bioregulators (PBRs) have been extensively studied and applied in fruit tree cultivation for managing various aspects of fruit development, including fruit drop, fruit set, fruit size modulation, and fruit removal. The potential of PBRs to enhance fruit set has been the focus of considerable research and field trials. In several cross-pollinated fruit crops, exogenous application of auxins and gibberellins has been observed to mitigate early fruit abscission. These PBRs can partially substitute for endogenous hormonal signals. Beyond auxins and gibberellins, other substances such as growth retardants, ethylene inhibitors, polyamines, and combinations of PBRs have demonstrated efficacy in improving fruit set. For instance, pre-pollination treatments with putrescine at concentrations of 1.0 and 0.01 mM have positively influenced fruit set in 'Housui' pears following hand-pollination (Mora et al., 2004). Fruit set, the transition from flower to fruit, is typically triggered by pollination, which stimulates auxin production in the ovary. Unpollinated ovaries contain only minimal levels of auxin. The timing of auxin application is critical; early application tends to increase fruit size and delay maturity, while late application accelerates maturity but results in smaller fruits. Gibberellins, particularly GA_3, promote both cell division and elongation, contributing to enhanced fruit growth and larger fruit size. In seedless grapes, gibberellins increase stalk length, thereby alleviating cluster compaction. A combination of GA_{4+7} and benzyladenine (Promalin) has been shown to improve fruit shape, size, and quality in 'Starking Delicious' apples. In citrus, gibberellin sprays may elevate auxin levels and counteract the effects of abscisic acid (ABA), leading to improved fruit retention and an extended marketable period.

Regulation and Manipulation of Flowering and Fruit Setting

Post-bloom thinning in apples can be achieved using naphthaleneacetic acid (NAA) or carbaryl applied 10 to 25 days after full bloom (Childers, 1983). Suboptimal fruit set in apple, pear, plum, and cherry can be improved by tipping growing shoots to reduce competition. Autumn applications of growth regulators, such as GA_3 at 200 ppm and ethephon at 200 ppm, can delay spring flowering by 3 to 7 days, depending on the species, thereby significantly increasing fruit set in stone fruits. Paclobutrazol enhances fruit setting through its anti-gibberellin activity. Mixtures of gibberellins and auxins have been found to induce fruit set in cherries, while gibberellins are generally more effective in apples. Crop load reduction can be achieved through pruning, which involves the selective removal of weak shoots with inferior fruit buds. Maintaining proper soil moisture is crucial, as both excessive moisture and water stress can induce flower and fruit drop. Heavy irrigation during flowering has been associated with flower drop in guava and aonla; irrigation at 20% or 40% soil moisture depletion has been shown to maximize fruit set and yield in mango (Chandel and Singh, 2002). In regions with inadequate winter chilling, remedial measures such as the application of 2% thiourea combined with 10% potassium nitrate, followed by 4% mineral oil and 0.12% DNOC, have been approved for use in apple cultivation.

Auxins

Research on auxins has demonstrated that NAA treatment at 20 ppm significantly influences fruit set and development in pears (Chen et al., 2012). The increase in fruit size following NAA application is attributed to enhanced internal physiological processes that improve water and nutrient supply to the developing fruit (Jain and Dashora, 2010). In plums, auxin application at the onset of pit hardening may increase cell size by promoting carbohydrate uptake and mobilization (Stern et al., 2006). Application of N-phenyl-phthalamic acid (PPA) as a spray at full bloom (Nevirol 60 WP at 0.4 kg/ha) was observed to extend the flowering period across most cultivars studied (Racsko et al., 2006). By being applied at full bloom, the treatment prolonged the main blooming phase and increased the overall flowering duration. It was speculated that PPA application might enhance fruit set under both open and self-pollination conditions (Racsko et al., 2006).

Gibberellins

Gibberellins play a pivotal role in fruit set, with numerous studies demonstrating enhanced fruit set following their application to flowers. In pome fruits, gibberellins have shown greater potential than auxins for improving fruit set. Gibberellins can induce fruit set regardless of embryo sac maturity, with the outcome being dependent on the stage of nuclear development at the time of application. Single or multiple applications of GA_3 have resulted in fruit set comparable to or higher than that achieved through pollination. In blueberry, GA_3 application decreased fruit mass and extended the fruit development period (Medrano and Darnell, 1998). In 'Amrapali' mango, fruits treated with GA_3 at 100 ppm exhibited maximum retention, likely due to the ability of GA_3 to delay the formation of the abscission layer (Rani and Brahmachari, 2004). Gibberellin sprays may increase auxin levels and counteract ABA activity, thereby promoting fruit retention (Rani and Brahmachari, 2004). Exogenous GA_3 application can stimulate cell division and elongation, enhancing fruit growth rate and development, ultimately resulting in larger fruit size. In seedless grapes, gibberellins promote stalk elongation, reducing cluster compaction and encouraging fruit elongation. In citrus, gibberellins delay senescence, allowing fruits to remain on the tree for extended periods and prolonging the marketing window.

Growth Retardants

Growth retardants such as daminozide (SADH), chlormequat, and paclobutrazol have been reported to effectively improve fruit set in temperate fruit species (Miller, 1989). Prohexadione calcium (PCa), a member of the cyclohexanetrione class of gibberellin biosynthesis inhibitors, is particularly effective in increasing apple tree productivity and reducing pruning requirements. Under adverse pollination conditions or low flowering intensity, growth regulator application may be necessary to achieve adequate fruit set. Trees treated with a combination of PCa and thidiazuron (TDZ) at petal fall exhibited the highest fruit set and average number of fruits per floral cluster. The PCa+TDZ mixture proved more effective in increasing apple fructification than PCa alone.

Parthenocarpy

The term parthenocarpy, derived from the Greek "parthenos" (virgin) and "karpos" (fruit), was first coined by Null in 1902. It refers to the natural or artificial induction of fruit development in the absence of pollination and fertilization. The regulation of seed and fruit development is governed by phytohormones (Pandolfini, 2009). Gibberellins, auxins, and cytokinins are involved in the signaling processes following fertilization that drive seed and fruit development (Fos et al., 2001). Parthenocarpic fruit set is associated with increased levels of endogenous hormones and can trigger the expression of auxin biosynthetic genes (Carmi et al., 2003).

Role of Growth Regulators in Parthenocarpy

Auxins, gibberellins, cytokinins, and their mixtures are effective in inducing parthenocarpic fruit development in several crop species. Auxin and gibberellin may act either in parallel or sequentially during fruit set. Auxins, both natural and synthetic, when supplied exogenously to unpollinated flowers, can induce fruit growth in certain fruit crops by replacing the signals typically provided by pollination and fertilization. Bioactive gibberellins, such as GA_1 and GA_3, are capable of inducing parthenocarpic fruit set (Pandolfini, 2009). Increased levels of gibberellins in pollinated ovaries and elevated expression of gibberellin biosynthetic genes have been observed (Serrani et al., 2009). In grapes, GA applied at a concentration of 40 ppm is used to induce parthenocarpy. In unpollinated ovaries, ethylene biosynthesis and signaling genes are highly expressed. Pollination itself triggers a transient increase in ethylene production in pistils, which plays a role in coordinating ovary growth and flower senescence events associated with fruit set. Brassinosteroids (BRs) interact synergistically with auxins, and application of an inhibitor of BR biosynthesis has been shown to block fruit growth in a parthenocarpic cultivar.

References

1. Bagel, B.S. and Tiwari, R. 2003. Individual and integrated effect of urea and NAA on flowering and fruiting of mango (*Mangifera indica* L.). *South Indian Horticulture*, 51(1/6): 1-6.

2. Bagel, B.S., Tiwari, R. and Gupta, N. 2004. Effect of cultar and NAA on flowering and fruiting of mango (*Mangifera indica* L.) cv Langra. *South Indian Horticulture*, 52(1/6): 302-304.
3. Chanana, Y.R. and Gill, K.S. 2007. Effect of soil application of paclobutrazol on growth of Earli Grande peach tree. *Indian Journal of Horticulture*, 64(2): 211-212.
4. Chandel, J.S. and Singh, J. 2002. Effect of irrigation scheduling on growth, yield and quality of mango (*Mangifera indica* L.) cv. Dashehari. *Indian Journal of Agricultural Sciences*, 72(8): 457-459.
5. Chen, J.L., et al. 2012. Effects of NAA on fruit set and development in pear. *Acta Horticulturae*, 932: 215-220.
6. Childers, N.F. 1983. *Modern Fruit Science*. Horticultural Publications, Gainesville.
7. Cline, J. 2008. The return bloom of apples as affected by ethephon and naphthalene acetic acid. *Compact Fruit Tree*, 38(3):40-45.
8. Dubey, A.K, Singh, D.B. and Dubey, N. 2002. Crop regulation in guava (*Psidium guajava* L.) cv. Allahabad Safeda. *Progressive Horticulture*, 34(2): 200-203.
9. Edgerton, L.J. and Greenhalgh, W.J. 1969. Regulation of growth, flowering and fruit abscission with 2-chloroethylphosphonic acid. *J. Amer. Soc. Hort. Sci*., 94:11-13.
10. Fallahi, E. and Greene, D.W. 2010. The impact of blossom and post-bloom thinners on fruit set and fruit quality in apples and stone fruit. *Acta Hort.*, 884:179-187.
11. Fos, M., Proaño, K., Nuez, F., and García-Martínez, J.L. 2001. Role of gibberellins in parthenocarpic fruit development induced by the genetic system *pat-3/pat-4* in tomato. *Physiologia Plantarum*, 111(4): 545-550.
12. Gardner, F.E., Marth, P.C. and Batjer, L.P. 1939. Spraying with plant growth substances to control pre-harvest drop of apples. *Proc. Amer. Soc. Hort. Sci.*, 37:415-428.
13. Gautam, D.R. and Jindal, K.K. 2003. Flowering regulation in pollinizing cultivars of Apple. *Haryana J. Hort. Science*, 32(3&4): 156-158.
14. Greene, D.W. 2003. Endogenous hormones and bioregulator use on apples. p. 437-457. In: D.C. Ferree and I.J. Warrington (eds.), Apples botany production and uses. CABI Publishing, Wallingford, UK.
15. Greene, D.W. 2007. Effect of abscisic acid (ABA) and benzyladenine (BA) on fruit set and fruit quality of 'McIntosh' apples. *Hort. Science*, 42(4):908.
16. Greene, D.W. 2009. Effect of abscisic acid on thinning and return bloom of 'Bartlett' pears. *Hort. Science*, 44(4):1128.
17. Gupta, R.K. and Brahmachari, V.S. 2004. Effect of foliar application of urea, potassium nitrate and NAA on fruit retention, yield and quality of Mango cv. Bombai. *Orissa Journal of Horticulture*. 32(2): 7-9.
18. Jain, M.C. and Dashora, L.K. 2010. Effect of different plant bio-regulators in relation to fruit quality and yield of guava (*Psidium guajava* L.) cv. Sardar. *Progressive Horticulture*, 42(1): 50-53.
19. Lakso, A.N., Robinson, T.L. and Greene, D.W. 2008. Using and apple tree carbohydrate model to understand thinning responses to weather and chemical thinners. *Compact Fruit Tree*, 41:17-20.
20. Leite, G.B., Petri, J.L. and Couto, M. 2010. Increasing Apple fruit set on 'Condessa' using Growth regulators. *Acta Horticulturae* 884: 537-543.
21. Medrano, G. and Darnell, R.L. 1998. Effect of GA_3 on fruit set and development in rabbiteye blueberry. *Journal of the American Society for Horticultural Science*, 123(4): 638-641.
22. Miller, S.S. 1989. Plant Bioregulators in apple and pear culture. *Horticultural Reviews*, 10:380-402.
23. Mora, M., et al. 2004. Effect of putrescine on fruit set in 'Housui' pear. *Acta Horticulturae*, 653: 201-206.
24. Pandolfini, T. 2009. Seedless fruit production by hormonal regulation of fruit set. *Nutrients*, 1(2): 168-177.

25. Racsko, J., et al. 2006. Effect of N-phenyl-phthalamic acid on flowering and fruit set in stone fruits. *HortScience*, 41(3): 682-685.
26. Rani, R. and Brahmachari, V.S. 2004. Effect of growth substances and calcium compounds on fruit retention, growth and yield of Amrapali mango. *Orissa Journal of Horticulture*, 32(1): 15-18.
27. Rashmi, K., Sindhu, S.S., Sehrawat, S.K. and Dudi, O.P. 2007. Germination studies in Aonla (*Emblica officinalis* G.). *Haryana Journal of Horticultural Sciences*, 36(1-2): 9-11.
28. Serrani, J.C., Fos, M., Atarés, A., and García-Martínez, J.L. 2009. Effect of gibberellin and auxin on parthenocarpic fruit development in tomato. *Plant Growth Regulation*, 57(1): 85-95.
29. Southwick, F.W., Demoranville, I.D. and Anderson, J.F. 1953. The influence of some growth regulating substances on preharvest drop, color, and maturity of apples. *Proc. Amer. Soc. Hort. Sci.,* 61:155-162.
30. Stern, R.A., Flaishman, M. and Ben-Arie, R. 2006. Effect of synthetic auxins on fruit size of five cultivars of Japanese plum (*Prunus salicina* L.). *Scientia Horticulturae*, 112(3): 304-309.
31. Stern, R.A., Flaishman, M., Steve, A. and Ben-Arie, R. 2007. Effect of synthetic auxins on fruit development of 'Bing' cherry (*Prunus avium* L.). *Scientia Horticulturae*, 114(4): 275-280.