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# Influence of Growth Regulators on Canopy Management of Fruit Crops- A Review

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**ABSTRACT: This review examines the effect of growth regulators on canopy management in fruit crops, focusing on the development and maintenance of their structure in relation to size and shape in order to achieve optimal productivity and fruit quality. Some Plant Growth Regulators (PGRs) are chemical substances that modulate natural hormonal functions to affect plant growth and development. PGRs can be utilized to enhance or decrease the height of plants. Many producers recognize that plant growth retardant is an effective tool for controlling plant development, such as Paclobutrazol helpful in significantly lowering the tree's height and canopy volume. Promalin encourages and morphactin hindered vegetative development at numerous sites with reduced canopy surface area. Ethrel was the only plant growth regulator increasing vegetative shoot growth in non-bearing apple trees, as well as the canopy management of guava orchards. Consequently, there is immense scope for improvement in comprehending the effect of growth regulators on the canopy management of different fruit crops. The major challenges in this area is that it is difficult to manage proper length width of canopy through training, pruning and also it require skill labors and proper time management to manage canopy. Here in this review, we explained alternative way in different fruit crop to manage canopy using some new growth promoters and growth inhibitors to manage canopy easily or effectively.**

**Keywords:** Canopy, PGRs, growth promoters, inhibitors, fruit, management.

## INTRODUCTION

Canopy management refers to the physiology behind the connection between vegetative growth and yield. The ultimate objective of canopy management is to optimise carbon allocation in fruit sinks without affecting the growth and development of other tree parts. The physical component of the canopy of a fruit tree consists of stems, branches, shoots, and leaves. The density of the canopy is determined by the leaf volume and size. The volume, length, and orientation of the stem and shoots define the architecture of the canopy. In order to maximise output and quality, fruit tree canopy management involves the growth and maintenance of the structure in terms of size, shape, branch direction, and light interception. In three-dimensional approaches, the basic canopy management strategy for a perennial tree is to maximise land use and environmental conditions for higher productivity. The influence of temperature, light, humidity, and tree vigour on the yield and quality of fruit, as well as the manipulation of tree canopies by means of training systems, pruning techniques, and the application of growth retardants, in order to optimise use and harvest. Due to the canopy's excellent light absorption and distribution, these systems produce abundant, high-quality fruits (Kumar *et al.,* 2020). The major research gap in this area is that most of the fruit orchards present are old and unproductive. Due to lack of regular canopy management practices, they become senile and there is a decline both in quality and quantity of produce after some period of time. Because of this orcharding becomes economically non-viable and non-remunerative. For overcoming this problem, we manage the canopy using traditional method training pruning and using new growth promoters growth inhibitors.

In order to maximise yield and quality, fruit tree canopy management involves the growth and maintenance of the trees' structure in proportion to their size and shape. Most orchard crops, particularly those grown in temperate and tropical climates, absorb less than 70 percent of radiated light, needing intensive canopy management to increase light absorption and crop yield (Whiley *et al.,* 2013).

ABA canopy spraying of sweet cherry trees alters fruit quality parameters in a cultivar dependent manner reproducible variations in sweet cherry fruit quality parameters in ABA canopy sprayed 'Lapins' cultivar trees were detected in consecutive seasons (improving fruit color but reducing fruit size and firmness) Canopy spraying of sweet cherry trees with the ABA biosynthesis inhibitor, NDGA, altered fruit color and size in the mid/late-maturing cultivar ('Lapins'), but not the early-maturing cultivar (Glen Red) Time *et al.* (2021). The canopy management system is made up of various parts, including rootstock/variety selection, training and pruning, the application of growth regulators, etc. fruit-producing tree's canopy is its physical structure, which consists of its stem, branches, shoots, and leaves. The number and shape of the leaves affect canopy density. The quantity, length, and orientation of the stem, branches, and shoots all affect canopy architecture. The term "canopy management" refers to an analysis of the physiology of light transmission and absorption, which are essential elements of overall tree productivity. The amount of incoming radiation and the proportion of radiation that is blocked by tree canopies are the key variables that determine. The management of canopy development is the most crucial factor affecting the productivity of fruit crops (Goswami *et al.,* 2014).

Most temperate fruits benefit from high density planting and canopy control for higher yields of high-quality fruit per unit area. has already assumed the lead in significant fruit-growing regions. However, with the introduction of growth inhibitors, pruning, and training techniques, the idea of high density planting is gaining popularity in topical and subtropical fruit. By regulating the plant canopies through standardising the training and practises, high density planting orchards may be taken advantage on Pal *et al.* (2016).

**The Ideal Canopy's Characteristics and Working Mechanism.** For best output and quality, fruit tree canopy management involves the growth and maintenance of the structure in terms of size and form, branch orientation, and light interception. It must have an enough number of fruiting units, allow sufficient light and ventilation into the canopy, and have sufficient foliage to maintain the fruits and shield them from sunburn. It prevents parasitic leaves by preventing foliage overlap. It is capable of providing effective spray coverage. Avoid fostering a microclimate conducive to the spread of pests and illnesses.

**Training for canopy management.** Training is the process of tying, trimming, attaching, or arranging a plant in order to give it a particular form. Improve the crotch angle between scaffold branches by managing and regulating the tree's structure and by constructing a robust tree framework would attain a balance between the vegetative and reproductive development of the tree. Also, it makes simpler for sunlight to reach all parts of the tree. In practise, open centre system, central leader training, modified leader system, etc. are among the various types of training.

**Pruning for canopy management.** Pruning is the removal of plant elements such as buds, matured shoots, and roots to control the direction and amount of growth and preserve a desirable form. Heading back and thinning are two of the most efficient pruning techniques. Crossing or interfering branches, as well as suckers and water shoots, must be removed. To regulate the growth and fruiting rate, it is possible to manipulate the shoot's growth, vigour, and orientation. induce consistent bearing. For high-density planting, it is possible to regenerate old, senile orchards if plant sizes are kept in check and excessive sun exposure is avoided. Diseases and insects must be managed (Parkhe *et al.,* 2018).

**Management of crop canopies using PGRs (Fig. 1).** A properly regulated environment with a regimen of appropriate cultural practices maximizes crop yield.

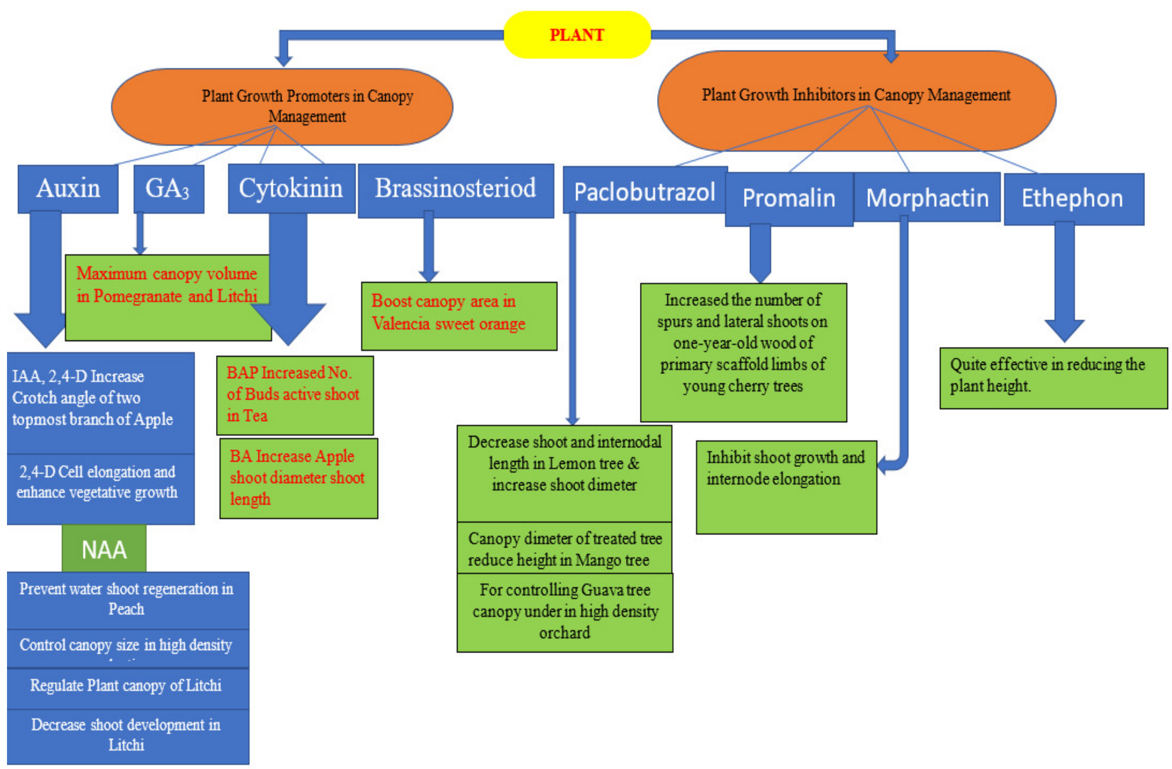


**Fig. 1.** Different Plant growth promoters and Inhibitors for canopy management.

A PGR should be utilized to produce crop responses that are not achievable by conventional crop management (e.g., controlling height or inducing branching). The production of tree fruits needs the application of growth regulators. These regulators can be employed to thin or set the crop, remove or retain the crop till harvest, boost fruit colour, and regulate maturity. Additionally, growth regulators can be employed to halt excessive vegetative development, alter the form of a tree, and initiate fruiting.

**Different growth promoters for canopy management (Table 1)**

**Auxin.** In many plant species, the main branch apex develops primarily, while axillary bud development is hindered. Apical dominance describes this phenomenon. When the stalk apex is detached, the dormancy of such axillary buds is disrupted and they begin to grow. Auxin produced by an undamaged shoot apex inhibits axillary bud development, but cytokinin produced by decapitating the shoot apex promotes axillary bud development (Shimizu *et al.,* 2009). The application of Auxin paste 1 percent IAA or 0.15 percent 2, 4-D to the decapitation wound of a young apple tree caused the crotch angle width of the two upper branches to rise significantly.

It was discovered that the use of NAA in "Fuji" apples drastically reduced shoot development and regrowth rate. Two or three applications of NAA (60-70 days after full flowering) at 10 to 40 mg/l can modulate canopy size in a high-density orchard setting, according to the authors (Choi and Huh 2001). Agnihotri *et al.* (2013) found the greatest increase in canopy spread in N-S and E-W direction. This may be the result of rapid auxin absorption, which increased endogenous auxin levels, resulting in quicker vegetative development and cell elongation.

It has been shown that confinement pruning can reduce the height of a peach tree's canopy. However, auxin paints should be applied to significant pruning wounds to limit water shoot regrowth below them. Although gummosis is caused by the treated cut, 1 percent NAA appears to be the most effective concentration in the paint. When sprayed as an aqueous solution on the bark, NAA at a concentration of 0.5 percent is more effective at inhibiting shoot development. This kind of pruning has little effect on the development of the tree as a whole, but the yield is lowered the next season due to fewer but larger fruits. Due to shoot growth in the lower half of the tree, this region may be suitable for tree structure rehabilitation (Blanco and Gomez-Aparisi 1984). The plant canopy of Litchi (*Litchi chinensis* Sonn.) cv Purvi as influenced by various amounts of plant growth regulators of foliar spray of NAA (30 and 50ppm) (Gaurha *et al.,* 2021).

**Gibberellic Acid.** The volume of the pomegranate canopy was drastically influenced by the administration of various concentrations of growth regulators. The effect of $GA_3$ on cell elongation and expansion may be responsible for the greatest increase in canopy volume. Increased water and nutrient absorption as a result of forceful swelling pressures led to the relaxation of cell walls, which facilitated better plant development, leading in greater plant height and spread, and ultimately a bigger canopy volume. Consistent with the findings of Moon *et al.* 2003 in mandarin, Sharma (2004) in apple, Saleem *et al.* (2007) in sweet orange, and Kumar *et al.* (2012) in strawberry the effect was clearly observer. Gaurha *et al.* (2021) disclosed that the effect of gibberellic acid was also seen on the size of the litchi canopy.

**Cytokinin.** The type and height of pruning, in addition to the application of cytokinin like BAP affect the growth of trimmed tea plants. Using 60 ml of cytokinin in conjunction with a 60 cm pruning height produced the best outcomes in terms of the number of buds and active shoots on trimmed tea plants (Dewi *et al.,* 2019). In an experiment conducted by Sharma *et al.* (2018) it was discovered that apple types Early Red One, Gale Gala, Red Chief, and Vance Delicious generated significantly more budwood when subjected to varied levels of pruning and benzyladenine (BA). It was determined that returning to 20 cm + BA (500 ppm) was the best treatment for boosting graftable scion wood, total number of shoots, number of lateral shoots, tree spread, and tree volume.

**Brassinosteroid.** This group is the sixth novel plant growth hormone and was recently added to the classical hormones category. Flowering initiation and termination, canopy architecture, micropropagation, cell division and elongation, vegetative development, blooming, fruit set, ripening, quality, and yield are all controlled by BRs (Baghel *et al.,* 2019).

**Table 1: Different plant responses with plant growth promoters.**

| Diff PGR | Concentration | Plant Response | References |
|---|---|---|---|
| NAA | 10 to 40 mg/l | Control canopy size in high density orchard. Apple (cv. Fuji) | Choi and Huh (2001) |
| NAA | 30 to 50 ppm | Regulate plant canopy of litchi | Gaurha *et al*. (2021) |
| $GA_3$ | 75 ppm | Maximum canopy volume in pomegranate | Moon *et al*. (2003) |
| $GA_3$ | 30 & 50 ppm | Maximum plant canopy in Litchi | Gaurha *et al.* (2020) |
| Cytokinin BAP | 60 ml | Increased no. of buds active shoot in pruned tea plant | Dewi *et al.* (2019) |
| BA | 500 ppm | Increase average shoot length shoot diameter, internodal length in Apple cultivar. | Sharma *et al.* (2018) |
| Brassinosteroid | 0.1 Micromolar (18.6ml/100 gallon) | Boost canopy area in Valencia sweet orange | Sutton *et al.* (2000) |

The application of BRs to the entire canopy resulted in a delay in senescence and leaf abscission in older leaves. Therefore, the delay in senescence and leaf abscission mediated by exogenous brassinosteroids in papaya plants is related to leaf age (de Assis-Gomes *et al.,* 2018). Sutton *et al.* (2000) revealed in a recent study, that biweekly application of homo-brassinolide at a dosage of 0.1 micromolar (18.6 ml/100 gallons) increased canopy area photosynthesis, fruit.

**Growth inhibitors for canopy management (Table 2).**

Due to their effect on reduced tree height, canopy size, and spread, growth retardants have a substantial impact on the economic yield of fruit crops by allowing more trees to be planted on the same amount of land. This has resulted in an increase in fruit production at the expense of the cost of the chemical and its application. In agriculture, however, only growth retardants that have been formally registered and evaluated with no adverse effects on persons or the environment will be allowed for use (Umar and Akash 2008).

**Abscisic acid.** ABA "on-tree" fruit dipping treatment in the 'Lapins' cultivar improves sweet cherry fruit color without negatively affecting fruit size, whereas ABA canopy spraying improves fruit color but decreases fruit size. These finding suggests that the decrease in fruit size in response to the ABA canopy spraying may be due to the effect of ABA on the tree foliage Time *et al.* (2021).

**Paclobutrazol [Cultar, Bonzi].** The paclobutrazol @ of 1.5 g a.i. per tree was applied in soil drench of mango cv. Langra in March for first year and October for second. The minimum vegetative growth and maximum fruit yield was observed in the pruning method which was soil drenched with paclobutrazol. Thus, light pruning with application of paclobutrazol is able to restrict the canopy growth with enhanced fruit production during the off-season of mango (Kumar *et al.,* 2020).

The most frequent uses of the cultar are to induce flowering during the off-season, control tree vigour for HDP (canopy management), boost fruit set and production, and enhance fruit quality when applied to the soil. However, the disadvantage of the cultar is that it has a relatively high persistence in both mango soil and fruit. Studies aiming to adjust the dosage of cultar applied to each cultivar will enable the formulation of recommendations for more effective applications, which can not only provide quality fruit production throughout the year but also lower the risk of residues in the soil, trees, fruit, canopy and environment of the mango orchard (Kumar *et al.,* 2021).

For two consecutive years, high-density peach plantings were sprayed with cultar (paclobutrazol) foliar sprays one month after full bloom. At a concentration of 1500 ppm, Cultar lowered plant height, extension growth, and shoot internode length. In immature peach plants, 1000 ppm Cultar exhibited the most effective outcomes in restricting both vegetative growth and fruit production (Kumar *et al.,* 2005). Paclobutrazol uses in soil and foliar sprays applied to high-density plantings of sweet cherry, peach, and plum lowered vegetative growth for 2–3 years following treatment, resulting in a proportional reduction in pruning weight and labour expenses, as well as improved floral bud development and fruit set. Depending on the concentration, method, and timing of application, fruit output per unit canopy volume rose by up to five times in sweet cherry, twice in peach, and once in plum, depending on the concentration, method, and timing of application (Stan *et al.,* 1988).

In an experiment, paclobutrazol was sprayed at varying concentrations on the "Lisbon" lemon trees. At 500, 1000, and 2000 ppm, paclobutrazol decreased shoot and internode length while increasing shoot diameter. At 1000 and 2000 ppm, paclobutrazol decreased the length of the shoot and internodes while increasing the width of the shoot. At a concentration of 2,000 ppm, paclobutrazol considerably decreased the number of nodes. Initial and final fruit set only increased significantly one year following paclobutrazol therapy (Smeirat and Qrunfleh 1989).

Six-year-old mango plants that were planted in a high-density system were severely pruned (2.5m × 2.5m). The soil was sprayed with paclobutrazol at a rate of 1.5 g/m$^2$ three weeks after the appearance of fresh flushes. During the test, five vegetative flushes were found. The third and fourth flushes of the treated trees were much shorter than those of the control trees, as were their internodal lengths. The height and spread of the canopy diameters of treated trees were reduced by 19.33 percent and 15.81 percent, respectively, in just one year. As a result, the canopy size was optimised for high density planting, whereas the canopy of the control trees became overlapping (Charnvichit *et al.,* 1989). The growth inhibitor paclobutrazol was sprayed over the soil at the base of 'Delicious' and 'Golden Delicious' apple trees. A single spray per tree in 1979 inhibited the development of terminal shoots for several seasons (Williams, 1983).

Canopy management comprising the application of PBZ and ethephon to restrict growth and boost plant population per unit area may be utilized to increase guava orchard output, according to the study's findings. The current study indicated that PBZ and ethephon had a significant impact on the vegetative growth of guava plants. PBZ at 500 ppm, which exhibits the largest growth retarding impact, might be researched further for managing guava tree canopies in high-density planting, taking into account fruit quality and economic issues (Brar, 2010).

**Promalin.** Promalin stimulates the development of side branches in young cherry plants. Promalin (a combination of $GA_{4+7}$ and 6-benzyladenine) increased the number of spurs and lateral shoots on one-year-old wood of primary scaffold limbs of young cherry trees when treated at bud swell and bud bust. Painted applications had more consistent outcomes than sprayed ones. Promalin-induced lateral shoots had broad crotch angles, and the overall length of shoot development on three-year-old cherry trees treated with promalin was greater than twice that of control plants (Veinbrants and Miller 1981).

**Morphactins.** It is known that morphactins hinder shoot growth and internode elongation (Schneider, 1970). They have a systemic effect, inhibiting current activity and the formation of new meristematic tissue. By changing the typical pattern of cell division in these tissues, they harm or impede the normal development of organs that are beginning to form after application (Merck *et al.,*1965).

Morphactin-treated trees produced more flowers, but also hindered vegetative development in multiple sites, resulting in a 20–30% decrease in canopy surface area. Treatment with morphactin decreases root development throughout the growing season, which may be related to impacts on vegetative growth, blooming, and water and nutrient absorption (Blaikie *et al.,* 2004).

**Ethylene.** Ethrel is the only available plant growth regulator that improves floral bud development while decreasing vegetative shoot growth in apple trees that do not generate fruit. Use of ethrel as a mild spray on non-bearing trees with a frame structure one to two weeks after peak bloom. induces a chemical stimulus that suppresses terminal growth for two to three weeks. Also, ethephon serves as a ripening hormone, promoting ripening and suppressing growth. At higher concentrations (500-3000 ppm), ethephon has been demonstrated to be quite effective at reducing plant height (Mohammed *et al.,* 1984). In a guava meadow orchard, ethephon was highly effective at reducing plant height (Singh, 2006). Increasing plant density per unit area and controlling growth using PBZ and ethephon may be used to increase yield in guava plantations (Singh, 2006). The application of exogenous ethephon influences the volume of the tree canopy with the least canopy volume and leaf area (Brar and Bal 2011).

**Chlormequat chloride (CCC).** However, it was noted that plants had a minimum number of panicles. As a result, these synthetic growth inhibitors will be used to govern Litchi's canopy and flowering more effectively (Gaurha *et al.,* 2021).

**Table 2: Different plant responses with plant growth retardant.**

| Diff PGR | Concentration | Plant Response | References |
|---|---|---|---|
| Paclobutrazol | 500 ppm | Utilized for regulating guava tree canopies under high density planting | Brar (2010) |
| Promalin (mixture of GA4+7 and 6-benzyladenine) | 500 ppm | increased the number of spurs and lateral shoots on one-year-old wood of primary scaffold limbs of young cherry trees | Veinbrants and Miller (1981) |
| Morphactins | 300 ppm | Inhibit shoot growth and internode elongation | Schneider *et al.* (1970) |
| Ethephon | 500-3000 ppm | quite effective in reducing the plant height. | Mohammed *et al.* (1984) |

## CONCLUSIONS

This review leads us to the conclusion that some growth regulators and growth inhibitors play an effective role in canopy management, such as the application of Auxin paste to increase the crotch angle width of apples and the application of NAA to reduce shoot growth and control canopy size in high density orchard systems. Different pruning levels and benzyladenine (BA) were significantly efficient in enhancing apple cultivar budwood yield. Red Chief, Early Red One, Gale Gala, and Vance Delicious Significant effects of growth retardants on reduced tree height, canopy size, and spread Paclobutrazol soil and foliar sprays used to high density plantings of sweet cherry, peach, and plum decreased vegetative growth for two to three years. The application of different concentrations of paclobutrazol to "Lisbon" lemon trees decreased shoot and internode length while increasing shoot diameter. Also, three weeks later, the soil was sprayed with paclobutrazol at a rate of 1.5 $g/m^2$ and their internodal lengths were significantly shorter. In just one year, the canopy diameters of the treated trees were lowered by 19.33 percent in height and 15.81 percent in width. The size of the canopy was optimised for dense planting. Promalin stimulates the development of side branches in young cherry plants. It is known that morphactins hinder shoot growth and internode elongation. Additionally, ethylene causes the commencement of flower buds and is therefore effective in crop canopy management. Hence, in future there is scope for canopy management using these new growth hormones for better productivity.

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**Conflicts of Interest.** None.

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