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Recent trends of using plant growth regulators in propagation, improving quality, yield, and fruit set of fruit crops: A Review

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Abstract
Phytohormones are organic molecules produced naturally in higher plants and modulate growth or other physiological functions at locations remote from their production sites. Their concentrations are very small and they act at a distant site. A modification in the efficiency of production, product quality, or enhanced cosmetic appeal could increase the value of fruit trees significantly. Furthermore, they affect fruit set, retention, yield, and quality. When plant growth regulators are applied, a better yield is achieved because they improve the internal physiology of developing fruits, which improves fruit set and reduces fruit drop, while also correcting various physiological disorders that decrease quality and yield. Auxins, gibberellins, ethylene, cytokinins, growth regulators, and growth inhibitors are a few of the factors that influence plant growth. Phytohormones also control genetic expression. The use of growth regulators has become a standard part of agro-techniques for a majority of cultivated plants, in particular for fruit trees. So far in fruit crops, plant growth regulators have been widely used for vegetative propagation via cuttings, air layering, germination, in-vitro propagation, etc. Discover that NAA was useful in controlling the two most serious problems of apple production: first is biennial bearing and second is pre-harvest dropping. Discoveries of gibberellins and cytokinins led to increased commercial use of these hormone products for various purposes including improved fruit shape, increased consumer value through blemish-reduction, and optimized tree architecture, which can be achieved through overcoming apical dominance. Natural hormone abscisic acid shows the potential to overcome plant stress and increase early fruit harvest. In recent years, 1-MCP has revolutionized pome fruit storage by increasing post-harvest life and improving fruit storage quality.

Keywords: plant growth, improving quality, fruit set, fruit crops

Introduction

Phytohormones are organic molecules produced naturally in higher plants and modulate growth or other physiological functions at locations remote from their production sites. PGRs are called bio-stimulators or bio-inhibitors that help regulate plant metabolism by stimulating or inhibiting specific enzymes or enzyme systems. Auxins, gibberellins, ethylene, cytokinins, growth regulators, and growth inhibitors are a few of the factors that influence plant growth. Phytohormones also control genetic expression. The first hormone to be discovered in plants, it was auxin, second and third was gibberellin or cytokinin. The plant hormone was named phytohormones by Thiemann Thiman (1963), (these hormones are synthesized in plants) to distinguish them from animal hormones. Plant growth regulator sprays are used to improve fruit size either directly by encouraging cell division or indirectly by reducing fruit number through the use of plant hormones that inhibit flower formation or encourage flower or fruit abscission from the plant. Plant growth regulators (PGRs) such as Gibberellic acid (GA_3), Naphthalene acetic acid (NAA), 6-benzyladenine (BA), 6-Benzylaminopurine (BAP), and 2-chloro-4-pyridyl-N-phenylurea (CPPU) are used on fruit crops primarily to improve fruit qualities, such as size and color, firmness and shape, decrease seed number, prevent the storage and reduce variability boost production.

In the world, India ranks second in the case of fruit production after China, with10.49% of global fruit production. Mango, walnut, grapes, bananas, and pomegranate account for the majority of fruit exports to the country. India has the 1st rank in the world to produce bananas, mangoes, papayas, guavas, and pineapples. Approximately 76 percent of total fruit and vegetable production is used for fresh consumption, with a small amount of total fruit production (only 4%) being processed (Anonymous, 2017) [5]. As a result of the usage of plant growth regulators, several excellent achievements in terms of growth, production, and quality have been achieved in various fruit crops. The commercial application of plant growth regulators to manage fruit development was investigated by (Lawes and Woolley 2000). Plant growth regulators have become an important aspect of modern crop husbandry for improving the yield of high-quality fruits. Fruits are high-value commodities, thus a foliar application of plant growth regulators to increase yield and quality of fruit harvests is worthwhile. Exogenous plant growth regulators can be used to maintain optimal fruit settings. Auxins and gibberellins are commonly used to prevent fruit drop and increase fruit quality. Plant growth regulators control physiological responses such as branching, increase flower bud production, and thinning by promoting fruit/flower abscission. The pre-harvest decline is slowed, Enhance fruit set, Improve fruit shape, Support fruit ripening, Delay fruit ripening, control the Vegetative growth of a plant, increase fruit color. The foliar application of plant growth regulators has resulted in certain excellent successes in terms of growth, production, and quality in a variety of fruit crops (Suman *et al.*, 2017) [59]. Plant growth regulators improve the productivity of fruit provided to marketers and consumers while also increasing its availability (Lawes & Woolley, 2001) Exogenous use of growth regulators reduces the proportion of pre-harvest fruit drop, resulting in the increased total quantity of fruits. In most cross-pollinated fruit crops, foliar spray of auxin and gibberellins helps to avoid early fruit abscission by partially replacing the usual endogenous synthesis of these hormones. Besides auxins and gibberellins, growth retardants, ethylene inhibitors, polyamines, and a combination of bioregulators have all been reported to improve fruit sets. (Pandey, 1999) [46] discovered that the Plant bio-regulators improve the inner physiology of least-developed fruit in terms of improving the delivery of water, nutrients, vitamins, minerals, and other chemicals essential for their correct survival and prosperity, resulting in improved size, quality, and ultimately higher yields. Below are studies on the effects of plant growth regulators on plant propagation, quality, yield, and fruit set, retention, in fruit crops.

1. Effect of different plant growth regulators on the propagation of fruit crops:

The influence of plant hormones on the survivability of pomegranate (Punica granatum L.) hardwood cuttings was investigated by (Damar *et al*., 2014), in a complete randomized design, five growth hormones treatments were replicated three times: first control, second IBA (1000 ppm), third IBA (2000 ppm), fourth NAA (500 ppm) and fifth NAA (1000 ppm) (CRD Factorial). PGRs were examined on pomegranate hardwood cuttings by (Sharma *et al*. 2009). The highest rooting, root numbers, and root length were seen in semi-hard and hardwood cuttings when IBA 500 ppm + Borax 1 percent was used. Cuttings treated with IBA 500 ppm + Borax 1 percent, IBA 300 ppm + Borax 2 percent, and IBA 5000 ppm had the best field survivability. In comparison to semi-hardwood cuttings, hardwood cuttings react better to hormone therapy. In pomegranate cv. Kandhari, (Tripathi and Shukla, 2004) found that treatment of 5000 ppm IBA + 1000 ppm p-hydroxybenzoic acid results in the highest root percent (85%), number of roots/cutting (56.9%), length of longest roots (23.2 cm), and cutting surviving percentage (80.4%). (Baghel *et al.*, 2004) found that Paclobutrazol is used to assist limit the vegetative stage of mangoes while extending the reproductive phase.

(Gilani *et al.*, 2018) looked at the influence of the Indole butyric acid (IBA) growth regulator on guava cv. Safeda roots (T1 (50 ppm), T2 (100 ppm), T3 (150 ppm), T4 (200 ppm), and control (T0) amounts of IBA were used), For roots, one-year-old vigorous guava branches were selected and injured by completely removing two inches of bark right underneath the bud. Those wounds were coated with soil medium containing varying levels of IBA hormone or wrapped with plastic and knotted on both sides. After being rooted, air-layered plants were transferred to plastic bags and stored in plastic tunnels to retain humidity. Layers treated with 150 ppm IBA (T3) were effective, per the analysis of data. The length of the primary roots was greatest (0.83 mm) in the inadequately untreated layer and was smallest (0.57 mm) in the phyto-regulator (IBA 5000 ppm) layer. In different metrics of the root development, quality, root growth, and establishment of layers in the nursery, single or combined with NAA at a greater concentration like IBA 5000 ppm + NAA 5000 ppm (T9) was determined to be the best, (Das and Prasad, 2014). The highest and least shoot multiplication values were found in Morabbaee-Mashhad and Azayesh-Esfahan respectively (4.46 and 3.66 shoots/explants). In the 12 MS media with 1.5 mgL^{-1} IBA, meanwhile, all rootstocks exhibited the best rooting. Consequently, Azayesh-Esfahan had the most shoot proliferation it is (5.11 shoots/explant) and rooted (48.33 percent) of the rootstocks tested by (Ghanbari, 2014). Table 1 shows a few of the other impacts of PGR spraying on fruit set in several fruit crops.

Table 1: Effect of different plant growth regulators on the propagation of fruit crops:

PGR	Dose	Fruit verity	Impact	Application	References
IBA **NAA**	5000 ppm 5000 ppm	Litchi cv. purbi	Primary roots was maximum	one-year-old shoot	Das and Prasad, (2014)
IAA **IBA** **NAA**	100 & 200 ppm 100 & 200 ppm 100 & 200 ppm	Poncirus trifoliata L. x Raf Citrus paradisi Macf.	Highest rooting percentage	one-year-old shoot	Fadli *et al*., (2017)
IBA	1.5 mgL-1	Azayesh-Esfahan cv. of Apple	Maximum rooting percentage	*In vitro* propagation	Ghanbari,(2014)
IBA	5000 ppm	Dragon fruit	Best root growth	2 to 5 days old shoot	Ayesha and Thippesha (2018)
BA **Kinetin**	mgl-1	Almond cv. Amygdalus communis	Highest shoots per explant	one-year-old shoot	Akbas *et al.*, (2009)
BA	1.5 mgL-1	Jackfruit cv.Artocarpus heterophyllus Lam.	most effective for shoot proliferation	*In vitro* propagation	Mannan *et al.* (2006)

IBA	7000 ppm	Dragon fruit	Best root growth	2 to 5 days old shoot	Srivastava *et al*., (2005)
IBA **IAA**	1.5 mgL-1 1.5 mgL-1	Citrus	Maximum rooting percentage	*In vitro* shoots	Tallón *et al*., (2012)
BA	1.5 mgL-1	Sahebi and Soltanin cv. of grape	Increased root number per shoot	Shoot apical meristems	Aazami, (2010)
IBA	150 ppm	Guava cv. Safeda.	Inducing rooting	one-year-old shoot	Gilani *et al.* (2018)

2. Effect of different plant growth regulators on the quality of fruit crops

In Gola, cv. of ber, NAA application At 20 ppm at the flower initiation stage, (Bhati and Yadav 2003) [11] noticed substantial improvements in TSS (19.44 °B), total sugar (10.69%), reducing sugar content is usually (4.2%), ascorbic acid (168.7 mg/100g pulp), & acidity (0.2%). (Kher, and Bhat, 2005) [33] also found that using NAA at 60 ppm as preharvest foliar spraying in guava cv. Sardar produced (11.6 percent) more TSS content when using NAA at 80 ppm produced (7.63 percent) more total sugars. (Yadav 2001) [64] discovered that applying NAA at 60 ppm in the guava fruits resulting the greatest rise in ascorbic acid and TSS while other concentrations of NAA and GA3 significantly enhanced total sugars when compared with the control in cv. L-49 of guava. When GA3 was treated 45, 50, 55, and 65 days after October pruning, the highest increase in bunch weight (473.82 g), the number of berries/bunch (112.00), and highest berry length (2.38 centimeter) compared with the control, was seen by (Gowda, Shyamalamma, & Kannolli, 2006) [27] in Thompson seedless cv. of grapes. (Sudha, Baskaran, & Leelavathi, 2007) [58] noticed In the sapota variety PKM 1, the foliar application of GA3 at 50 ppm 30 days before harvesting produced greater fruit firmness (3.45 kg/cm2), which improved fruit's its shelf life. According to (Chavan *et al*. 2009) [14], spraying NAA at 150 ppm at flowering stage, and next spray at fruit set, and the third spray during the stage of fruit development resulted in a higher TSS (20.15°B) of fruits with the lowest fruit acid content (0.211%), as compared to normal control (18.35°B and 0.228 percent, respectively. GA3 treatment at 150 ppm at pea stage in kalipatti cv. sapota was reported by (Patil *et al*., 2010) [47]. (Agrawal & Diskhit, 2010) [2] found that, In comparison to the control, resulted in greater fruit length, weight, and diameter. When NAA at 100 ppm was applied to sapota cv. Cricket ball, it resulted in a rise in fruit size (15.60 cm), fruit weight (6.18 g), pulp weight (69.75 g), fruit diameter and pulp thickness (2.87 cm), as well as a decrease in the amount of seeds per fruit when compared with the control. Table 2 shows a few of the other impacts of PGR spraying on fruit set in several fruit crops.

Table 2

PGR	DOSE	FRUIT VERITY	IMPACT	TIME OF SPRAY	REFERENCES
NAA	20 ppm	Bael cv. Pant Shivani	Increase Fruit chemical properties (enhance fruit TSS, Acid ratio, pulp content)	Two times (first one after 7 days of plant growth initiation and final spray during the last week of June)	Uniyal (2011)
NAA	10 ppm 15 ppm	Mango cv. langra	High TSS/acid ratio Highest ascorbic acid content;	fruit setting stage	Singh, Mandal, and Singh (2011)
NAA	30 ppm	Ber cv. Umran	Increase in fruit weight and size	Twice (3rd week of Oct& other after 1 month)	Arora and Singh (2014)
NAA	50 mg/L	Litchi cv. Bombai	High TSS/acid ratio Highest ascorbic acid content, total sugars	4 sprays (between Sept and Dec)	Dutta, Chakraborti, da Silva, Roy, and Samanta (2011)
NAA	40 ppm	Pomegrante cv. Bhagwa	Maximum fruit weight, size and volume; Increased TSS & total sugar	Full bloom stage	Anawal, Narayanaswamy, and Ekabote (2016)
NAA **GA_3**	50 ppm 20 ppm	Sapota cv. Cricket ball	Maximum fruit weight, size and volume; Increased TSS & total sugar	After pruning	Sahu, Patel, and Panda (2018)
NAA **NAA**	40ppm 20ppm	Mango cv. Himsagar	Maximum fruit weight, size and volume; Increased TSS & total sugar	During fruit set stage	Bhowmick and Banik (2011)
NAA	75 ppm	Guava cv. Sardar	Highest fruit firmnes	Colour break stage (15 days before harvesting	Mandal, Dhaliwal, and Mahajan (2012)

NAA **GA_3**	50 ppm 30 ppm	Ber cv. Umran	Heist tss,fruit weight and size,lowest acid content	Twice (Oct & Nov)	Gill and Bal (2013)
2,4-D **GA_3**	15 ppm 50 ppm	Pomegranate cv. Bhagwa	Higher Total sugars vitamin C, Maximum TSS & vit.-c	15 days after fruit set	Kishor, Maji, Govind, Meena, and Kumar (2016)
BA + GA4+7	25 ppm	Pear cv. Deveci	Highest TSS &lowest Titrable acidity	14 days after the peak bloom	Fatih, Fatih, Mustafa, and Mustafa (2009)
BA + GA3	25 ppm + 50 ppm	Pear cv. Arka	enhance fruit size and weight	14 days after the peak bloom	Canli and Paktas (2015)
GA_3 **BAP** **Boric acid**	100 ppm 100 ppm 250 ppm	Dateplam cv. Barhee	Enhance fruit quality, maximum TSS & sugars	Twice (1st at depressed period of fruit growth and 2nd one month after fruit)	Ashour *et al.* (2018)
GA_3	100 ppm	Grewia sub-inequalis (Phalsa	Enhance Reducing sugars, TSS: Acid content, pulp to stone ratio and minimum acidity	Twice (pre-bloom & post bloom stage)	Debnath (2010)
GA_3	60 ppm	Wax Apple	Highest pH	Pea stage	Al-Saif (2011)
GA_3	100 ppm	Apricot cv. Shadoo	Maximum pH	After 6 and 10 weeks of full bloom	Khajehjar, Rahemi, and Fallahi (2015)

3. Effects of different plant growth regulators on fruit set

A fruit set is a developmental phase in which a flower (ovary) transforms into a young fruit that will mature till maturity.

(Watanabe, *et al.,* 2008) [65] discovered that the 60% ratio of fruit set in cv. Ohrin and 7 percent ratio in non-parthenocarpic Fuji cv. of apple by the application of GA_3 and proposed that the usage of GA_3 before flowering triggers in parthenocarpic apple fruits. When 150 ppm NAA was applied at flowering time in sapota, it tends to result in more inflorescence number (54.0flower/shoot) and the fruit set (43.13fruit set/shoot) when compared with the control (Chavan *et al*., 2009) [14]. (Singh 2009) recorded a higher fruit set (84 fruits/spike) in mango varieties. Kensington pride to apply GA_3 (75 ppm) at the stage of flower bud differentiation. Table 1 shows the other effects of PGR application on the fruiting of various fruit crops. In Dashehari, a cultivar of mango, (Singh & Ram, 1983) [56] discovered that the spraying of Naphthlic acetic acid (40 ppm) at the time of pre-bloom stage with chlormequat (20 ppm) at the pea stage increased fruit holding capacity. Similarly, (Babu & Lavania, 1985) discovered that in autumn flowering, when NAA (5–10 ppm) and GA_3 (10–40 ppm) were spraying before the full bloom stage and after the full bloom in verity 1 lemon pant resulted in more fruit. In the case of Cricket ball verity of sapota, (Ray *et al*., 1992) [50], Discovered that the fruit set improved by spraying 100 ppm SADH followed by Gibberellins (100 ppm) and NAA (300 ppm) immediately before the flowering stage and after one month. Table: 3 shows a few of the other impacts of PGR spraying on fruit set in several fruit crops.

The proportion of fruit set is calculated by the following equation:

Fruits set (%) = (Number of fruits set/Total number of blossoms) × 100

Table 3: Effect of different plant growth regulators on fruit set

PGR	Dose	Fruit verIty	Impact	Time of Spray	References
NAA	20 ppm	Pant Shivani cv. of Beal	Increased fruit set	Two times (first one after 7 days of plant growth initiation and final spray during the last week of June)	Uniyal (2011)
NAA	125 ppm	Sapota cv. Kalipatti	Increased the number of flowers per branch; highest fruit set percentages.	During the stages of flowering or fruit set (Twice)	Dhananjay (2017)
NAA & **GA_3**	25 ppm 25ppm	Mango cv. Keitt	Fruit set and fruit yield per cluster and plant have risen.	NAA at full bloom stage and after one week GA3.	Nkansah, Ofosu-Amin, and Marouli (2012)
NAA	15 ppm	Cape gooseberry cv. Aligarh	Improved fruit set percentage	At fruit set	Kaur and Kaur (2016)

NAA	25 ppm	Grewia sub-inequalis (Phalsa)	The increased number of flowers per branch, fruit set, and the number of fruits per node have all increased.	Twice (once in the pre-bloom and again in the post-bloom stage)	Debnath (2010)
GA_3	30 ppm	Wax Apple	Maximum percentage of fruit set	The phase of little buds and petal falling stage	Tuan and Ruey (2013)
GA_3	200 ppm	Papaya cv. Red lady	Improved fruit set percentage	Thrice (After planting 30, 45, and 60 days,).	Hazarika, Sangma, Mandal, Nautiyal, and Shukla (2016)
GA_3	75 ppm	Custard apple	Increased percentage of fruit set	flowering stage & fruit set stag	Mahorkar, Naglot, Navsare, and Chavhan (2018)
GA_3 Boric acid, BAP	100ppm 250ppm 100ppm	Date palm cv. Barhee	Increased fruit set	depressed period of fruit growth and one month after fruit	Ashour, Mostafa, Saleh, and Hafez (2018)
Kinetin	50 microlitre/L	Almond cv. Non-Parei	Improved percentage of fruit set	Bloom at pink bud stage	Maita and Sotomayer (2015)
Brassinolide	0.1ml/l	Almond	Increased fruit set	At full bloom stage	Sotomayor, Castro, Velasco, and Toro (2012)
GA_{4+7} + 6BA	6 mg/L	Pear cv. Williams	Increased fruit set	At full bloom	Luz *et al*. (2014)
CCC	250 and 500 ppm	Guava	Enhance fruit set	flowering stage & fruit set stag	(Suman *et al*., 2017)
PPA	0.4 kg/ha	Apple	increase fruit set and Extended flowering time	Full bloom stage	Racsko *et al*., 2006
GA4+7 GA3	3% 2.7%	Pear	Improved final fruit size	Young Fruit period	Chen *et al*., (2012)
PCa+TDZ	330+12 ppm	Apple	Increase fruit set	Petal fall stage	Leite *et al*., (2010)

4. Effects of different plant growth regulators on fruit retention

According to (Nagargoje *et al.*, 2007) [43], In sapota var. Kalipatti, found that applying NAA Around 100 ppm during 50 percent flowering stage and subsequently at the pea stage, i.e. in Aug.–Sep. enhanced fruit survival as compared with control. According to (Chavan *et al.*, 2009) [14] in sapota var. Kalipatti, the treatment of Naphthalene Acetic Acid (150 ppm) was resulted in maximum fruit retention (18.77 fruits/shoot), as compared with NAA (100 ppm). The first treatment was sprayed at the flowering time, the secondary at the time of fruit set or the third at the time of fruit development. The Kallipati variety of sapota produced more fruits when sprayed with NAA various concentrations (25ppm, 50ppm, or 100 ppm) three times, the first at full bloom, the second and third at 15-day intervals. Using Urea (6% + 150 ppm) and NAA (150 ppm) at the pre-flowering stage increased the percentage of hermaphrodite flowers and the total number of flowers per panicle in mango cultivar Sunderja discovered by (Bagel and Tiwari 2003) [10]. In Amrapali verity of mango, application of Gibberellins @100 ppm at full bloom stage resulted in the highest fruit retention, according to (Rani and Brahmachari 2004) [28]. In Kalipatti verity of sapota, (Nagargoje *et al.*, 2007) [43] found that applying Naphathlic acetic acid At 100 ppm during 50 percent flower blooming and secondly at pea stage, i.e. in Aug.–Sept., enhanced fruit retention, followed by control. In Kalipatti verity of sapota, the spraying of Naphathlic acetic acid (150 ppm) resulted in maximum fruit retention (18.77/shoot), followed by Naphathlic acetic acid (100 ppm). The first treatment was sprayed at the time of flower initiation, the next at the time of fruit set, or the third at the time of fruit development (Chavan *et al.*, 2009) [14]. In the Kallipati cultivar of sapota, (Rathod and Amin 1981) discovered that applying Naphthlic acetic acid @ 100 ppm during full bloom stage, second and third spray at 15-day intervals resulted within that maximum fruit retention, and this was 5.3 percent higher followed by control. (Pandey 1999) [46] investigated the effects of GA_3 (15 ppm) or NAA (20 ppm) on fruit retention in Banarasi Karaka cv. of ber and colleagues discovered that both hormones resulted in increased fruit retention, with GA_3 (10.18%) or NAA (10.30%), respectively, as compared with the control. In the same way, using 2% urea and 20 ppm NAA resulted in better fruit retention in the Gola cultivar of Ber (Bhati & Yadav, 2003) [11]. When sprayed 14 days after blooming period in mango cv. Armani (Notodimedjo 2000) [45] found that 10 ppm of CPPU produced a maximum quantity of fruits and higher fruit retention when compared to any other hormones treatments. In the Banarasi Karka cv. of Ber, (Ghosh, Bera, Kundu, and Roy 2009) [24] discovered that NAA spraying at 25 ppm shortly after fruit set and second or third sprays at a 21-day interval after the fruit set, produced significantly maximum fruit retention (75%) when compared to control. Table 2 shows a few of the other impacts of PGR spraying on fruit retention in several fruit crops.

Table 4: Effect of various plant growth regulators on fruit retention

PGR	Dose	Fruit Verity	Impact	Time of Spray	References
NAA	20 ppm	Beal cv. Pant Shivani	Increased fruit retention	1st spraying after one week of growth initiation, and 2nd spray during the last week of June	Uniyal (2011)
NAA	200 ppm	Sapota cv. Kalipatti	Maximum fruit retention	Twice (1 month before flowering & at pea stage)	Bhujbal, Naik, and Kale (2013)
NAA	125 ppm	Sapota cv. Kalipatti	Increased fruit retention	During flowering and at the pea stage	Kaur (2017)
NAA	30 ppm	Ber cv. Umran	Minimum fruit drop	Twice (2nd fortnight of Oct & 2nd fortnight of Nov)	Gill and Bal (2013)
NAA	50 ppm	Mango cv. Amrapali	Highest fruit retention	Twice during pea stage fruit (at 21 days interval)	Ghosh (2016)
NAA GA_3	25 ppm 25 ppm	Mango (Keitt)	Increased fruit retention	NAA at full bloom and GA_3 a week later	Nkansah *et al.*, (2012)
GA_3	75 ppm	Custard apple	Minimum fruit drop & maximum no. of fruits/plant	Twice (Flowering and fruit set stage)	Dhananjay (2017)
GA_3 Boric acid BAP	100ppm 250ppm 100ppm	Date palm cv. Barhee	Increased retention and bunch weight	Depressed period of fruit growth and one month after fruiting	Ashour *et al.*, (2018)
GA_3	75 ppm	Custard apple	Highest fruit retention & no. of fruits/plant	Twice (1stat flowering stage &2nd at fruit set)	Mahorkar *et al.*, (2018)
GA_3	30 ppm	Wax Apple	Minimum fruit drop	Small bud and petal fall stage	Tuan and Ruey (2013)
GA_4	25 ppm	Persimmon cv. Costata	Increased retention and bunch weight	Twice: At pea stage and marble stage	Kassem, El-Kobbia, Marzouk, and El-Sebaiey (2010)
NAA	40 ppm	Mango cv. Bombai	Maximum fruit retension	After fruit set	Gupta and Brahmachari, (2004)

Merits and demerits of PGRs

Table 5

S.no.	Merits	S.no.	Demerits
1.	Plant growth regulation: Plant growth regulators (PGRs) are important for regulating plant development and improving the productivity and quality of horticultural crops. These phytochemicals help to increase fruit quality and output by regulating or directing specific physiological activities in the plant.	1.	side effects of excessive ethylene dosages:Senescence, chlorophyll loss, losses of plant organs, reduction of stem elongation, abscission of leaves and roots, and epinasty are all potential side effects of excessive ethylene dosages.
2.	Easy to use: PGRs are simple to apply since they may be used in various ways, including, soil-applied drenches for plants, and For fruit, seedling, seed, and dip treatments.	2.	Effect of Excessive cytokinin: Excessive cytokinin concentrations promote callusing in tissue culture, which has a detrimental effect on shoot beginning, proliferation, and elongation, as well as a reduced number of shoots and may disrupt with root induction. Discoloring of the leaves can also be caused by excessive concentrations of cytokinin.
3.	Economical: PGRs support growers to save cost and time by minimizing the need to maintain trees, lowering water and nutrient	3.	Lacunae: There is indeed a lack of knowledge of how PGRs work, as well as how, when, and where they should be employed for the best effects in

	demands, lowering labour needs, and enhancing overall plant quality, decrease the effect of infections and pest problems while also improving the overall efficiency.		various crops. To achieve a clear knowledge of the utilisation of PGRs in horticulture, more research is required.
4.	Diverse applications: PGRs can greatly enhance plant performance, and their impacts are frequently used as breeding objectives in horticulture crops, either using traditional methods or genetic modification. At various stages of development, PGRs can be exploited for various effects. To generate more fruits and flowers with greater consistency, improve fruit yield, fruit set and quality, and extend the shelf life of fruits.	4.	Awareness of sensitivity for use: PGRs are used at stages and concentrations that are quite specific. Plants may suffer unexpected harm if PGRs are applied at the wrong time or even in large doses.
5.	For controlling growth: Plant hormones help nursery and greenhouse growers save money and increase productivity. Low-dose applications of some of these PGRs are a cost-effective way to control proliferation. This helps in managing horticultural crops in gardens, orchards, and controlled cultivation much easier.	5.	know-how: Trained professionals must carefully follow the PGR instructions on the packaging in order to apply the product correctly. Because of the low doses necessary, the amount of PGRs to be ingested in milligrammes or micrograms must be precisely determined and an adequate solvent applied. Because gibberellins do not dissolved in the water, the solvents for them is ethyl alcohol.
6.	PGRs small dosages: must be applied under very small dosages to control typical plant processes such as root growth, plants height, node and internode growth, blooming, flower and fruit quantity, fruit, and several other reproductive characteristics.	6.	Greater dose of gibberellins can cause the following side effects: The use of high concentrations of gibberellins during germination initiation could have long-term consequences for seedling development.

Conclusion

Plant hormones had a considerable impact on growing Horticultural plants and influence the yield. Auxins and gibberellins are applied to prevent fruit drop and increase fruit quality. PGRs improve the vegetative growth of fruit plants, increase the number of flowers as well as enhance fruit shelf life. Under field conditions, a combination of synthetic and hormone-based Phytohormones have been utilized to improve stress tolerance and productivity of various horticultural crops. Despite the fact that there is a long list of PGRs that are widely applied to increase plant, development, growth, defense, and production efficiency, the molecular mechanisms behind their impacts are still unknown. Furthermore, their commercialization is reliant on a number of parameters, including their field durability, cost-effectiveness, inertness, ease of application, and responsiveness towards different conditions. Regarding the ever-changing and unpredictable climatic conditions, future studies may focus on developing mixed growth regulators that integrate mixture of various PGRs to resist many stresses. In a more efficient manner in order to achieve major effect on productivity and growth. Another factor that needs to be properly explored is the economic feasibility of marketing and selling PGRs from the perspective of both the agrochemical sector and users, small and marginal farmers. As a result, the topic of PGR-based research is still in formative stages and can be examined in better detail with the ultimate goal of developing a highly versatile and successful technology that can be delivered directly to farmers' fields to ensure long-term agricultural sustainability.

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