

Effective administration of plant growth regulators in Horticultural crops

Abstract

The use of plant growth regulators (PGRs) in modern horticulture is well established, more particularly horticulture in industrially advanced countries and their application is fast picking up in the developing nations as well. Natural and synthetic plant growth regulators have been used with increasing incidence to modify crop plants by changing the rate or pattern, or both, of their responses to the internal and external factors that govern development from germination through vegetative growth, reproductive development, maturity, senescence or aging, and postharvest preservation. The research review indicated that use of plant growth regulators, regulation of plant metabolism, control of flowering, effects on fruit set and development, control of abscission, Breaking of Seed dormancy and seed germination, enhancing and regulation of flowering, controlling flower drop, fruit thinning, fruit setting, parthenocarpy, Post-harvest management and extending shelf life of horticultural crops.

Keywords: Plant growth regulators, Propagation, flowering and fruiting, Shelf life in Horticultural crops

Introduction

Plant growth regulators (PGRs) are organic compounds, other than nutrients, that modify plant physiological processes. PRGs, called biostimulants or bioinhibitors, act inside plant cells to stimulate or inhibit specific enzymes or enzyme systems and help regulate plant metabolism (Bashir et al. 2021). Plant hormones, also known as phytohormones, are naturally occurring chemicals generated by plants that control growth. They are both flexible chemical regulators of plant development and in control of it. Plant growth regulators (PGRs) are the name given to these chemicals when they are synthesised (Santner et al., 2009; Davies, 2010; Rademacher, 2015). They normally are active at very low concentrations in plants. The importance of PGRs was first recognized in the 1930s. Since that time, natural and synthetic compounds that alter function, shape, and size of crop plants have been discovered. Today, specific PGRs are used to modify crop growth rate and growth pattern during the various stages of development, from germination through harvest and post-harvest preservation. Several environmental and endogenous signals must be integrated into the process of plant growth and development. These signals, along with the plant form is determined by an

intrinsic genetic programme. Plant growth regulators are essential to this procedure. Classical groups or other chemicals are included in the main phytohormones and/or PGRs. Among these are indol-3-ylbutyric acid (IBA) and indol-3-ylacetic acid (IAA), abscisic acid (ABA), gibberellic acid (GA₃), 1-naphthylacetic acid (NAA), 6-benzylaminopurine (BAP), benzyladenine (BA), chlormequat chloride (CCC), 2,4-dichlorophenoxyacetic acid (2,4-D), ethylene or ethephon (CEPA), jasmonate (JA, or yet, methyl jasmonates-MeJA), as well as brassinosteroids (BR), salicylic acid (SA), nitric oxide (NO), strigolactone (SL), and polyamines (like putrescine (Put), spermidine and spermine). Ascorbic acid (VC), alpha-tocopherol (VE), thidiazuron (TDZ), phenylureas (CPPU), and triazoles (TR) are other compounds. The new family of plant growth regulators known as Karrikins was also discovered in smoke (Chiwocha et al., 2009; Davies, 2010; Ullah et al., 2012; Rademacher, 2015; Fahad et al., 2016). Plant growth regulators have become indispensable in the field of horticulture due to its potential in improvement of flower production and Shelf life, altering the growth, flowering and propagation of plants. Among the plant growth regulators gibberellins, auxin, ethylene, cytokinins, inhibitors and growth retardants are of immense use of the horticulturist (Janowska and Andrzejak, 2023).

The idea of the existence of auxins in plants was for the first time conceived by **Charles Darwin** in 1881. Subsequently, F.W. Went (1934) was able to collect the substance produced by the tip of the agar blocks by diffusion. The block was then cut into pieces and each piece was then cut end of coleoptiles which was responsible for curvature of tip towards light due to more growth of tissue on side which do not face direct light, Went named this substance as 'auxin' (Greek word Auxem means to grow) and concluded that no growth can occur without auxin'. Endogenous or exogenous Auxin is a requirement for initiation of adventitious roots in stems of cutting and air layering. It has been shown that the division of the first root initial cell are dependent upon either exogenous applied or endogenous auxin. Recent studies have substantially contributed to our understanding of the molecular mechanisms underlying the physiological role of auxin in plant development. Auxin is critical for the control of plant growth and also orchestrates many developmental processes, such as the formation of new roots.

Formation of performed root initials in stems is apparently dependent upon the native auxins in the plants plus an auxin synergist together, these had to synthesis of Ribonucleic acid (RNA) which is evolved in initial of the root primordial. Thimann and Went (1934) found that the relative amount of auxin present indigenous or applied was associated with the formation of root primordial. The synthetic root promoting auxin such as Indole Butyric Acid

(IBA) and Naphthalene Acetic Acid (NAA) have been found effective for rooting of cuttings and air layering alone or in combination. (Hartmann *et al.* 1960) stated that in Pear 200 ppm of IBA was found very effective in promotion of rooting of hard wood cutting. Pathak and Hariom (1982) observed that rooting potentiality of Jackfruit was improved by treatment of IBA + NAA (2500 ppm) or 2500 ppm IBA alone, while higher concentration of IBA proved supra optimal and their by reduced the rooting percentage. (Singh *et al.* 2001) reported that the application of IBA of 15000 ppm increased the survival percentage of Air layers in Mango. (Akwatuliral *et al.* 2011) investigated the influence of different rooting media and indole butryic acid (IBA) concentration on root and shoot development in stem cuttings of *Warburgia ugandensis*. Stem cuttings were treated with three different levels (0.3, 0.6 and 0.8% w/w) of IBA and one control i.e. no IBA and propagated in three rooting media (milled pine bark, top forest soil and sand) under non-misting propagators. Milled pine bark and 0.8% w/w IBA concentration gave the greatest number and longest shoots per stem cutting. (Kishore *et al.* 2001) conducted an experiment to observe the rooting of hardwood cuttings in sand and saw dust rooting substrate. Observation on the rooting behaviour of six Kiwi fruit varieties revealed that though, sawdust was a superior rooting medium for root initiation in Kiwi fruit hardwood cuttings, but subsequent root and shoot development was better in sand. The cultivars varied from each other only with respect to the magnitude of the rooting like IBA 3000 ppm was found to be suitable concentration for rooting. (Nagaraja *et al.* 1991) obtained maximum survival percentage in IBA 4000 ppm in hardwood and semi-hardwood cuttings that was 90.00 per cent and 80.00 per cent, respectively. In softwood cuttings, the maximum survival percentage was obtained in IBA 1000 ppm and NAA 3000 ppm that was 73.33 per cent. Response of hormone gibberellins was discovered by Kurosava, a Japanese scientist in 1926. The gibberellins together naturally occurring compound first isolated in Japan in 1829 from a fungus botanically known as *Gibberella fungikurai* (*Fusarium moniliforme*). It was first isolated from immature seeds of *Phaseolus cocineus* by Mac Millan and Suter (1958). These compounds display a remarkable diversity of physiological effects, including those on growth flowering, fruiting and dormancy (Bukavac and Wittwer, 1958; Brian, 1959; Stowe and Yamaki, 1957; Philney and West 1960). Comprehensive review of Published information on plant growth regulator was Compiled to determination the state of the art on the subject

Major Response of plant growth regulators in Horticultural crops

Plant Propagation and Seed germination

(Hutchinson et al 2014) reported that the use of TDZ at low concentrations was as effective as combined auxin (NAA) and cytokinin (BAP) in evoking shoot regeneration and elongation as well as the number of leaves formed per shoot during *in vitro* propagation of *Alstroemeria aurantiaca* cv. 'Rosita' from shoots tip explants. Paul and aditi, 2009 found that the most efficient concentrations of hormones (IBA and NAA) which enhance rooting of layering and improve the rooting characters like root length, diameter, branching, hardness and the relation of rooting with sprouting in water apple. Samir Z. (El-Agamy et al., 2009) studied that Shoot tips of 2-3 cm long of two pomegranate cultivars (Manfalouty and Nab El-Gamal) were cultured on three different media at full strength, namely Murashige and Skoog; (MS), Nitsch & Nitsch; (NN) and Woody Plant Medium; (WPM). Woody Plant Medium (WPM) proved to produce best vegetative growth characteristics compared to MS and NN ones. BA at 1.0 mg/l induced high significant proliferation rate and shoot quality for two tested cultivars compared to kinetin. To induce rooting NAA at 0.25 mg/ (for Nab El-Gamal) and IBA at 0.25 mg/l (for Manfalouty) while IBA generally proved to produce higher number of roots per shoot. In addition, WPM at half-strength generally produced better plantlets compared to its full strength. Similar result were reported by (Mamta Sharma *et al*, 2000) in apple rootstock. (Arrillaga, I. *et al*.1990) investigated that the use of Various plant growth regulators in *in vitro* propagation in flowering ash, Shoot apices or nodal segments from aseptically grown seedlings or shoot apices from adult trees were used as initial explants. Result reported that the highest shoot multiplication rates were obtained when the explants were cultured for 30 days in liquid Rugini induction medium supplemented with BA followed by 30 days on solidified Rugini multiplication medium without growth regulators. Regenerated shoots were rooted on Heller medium containing auxins alone or in combination with BA. Rooting percentages up to 71% (juvenile material) or 50% (adult material) were obtained in the presence of NAA and BA, and were not improved by treating the basal end of the shoots with concentrated NAA solutions.

Flowering and fruiting

Many reviewer had reviewed that the effect of naphthalene acetic acid (NAA) as a plant growth regulator in reducing pre-harvest fruit drop and resulting in increased number of fruits and yield in tomato crop. (Khan *et al.*, 2002) reported that the spray application of naphthalene acetic acid (NAA) had significant effects on increasing number of tomato/plant, weight of tomato per fruit and fruit yield/plant compared with control. (Seneratna *et al.*, 2000) indicated that aspirin and salicylic acid induced multiple stress tolerance in bean and tomato plant. Tiwari and Lal, 2007 reported that

the effect of naphthalene acetic acid (NAA) all the treatments gave significantly higher yield than control. Maximum yield (88.00 kg/tree) was recorded with one leaf pair pruning during winter season. Overall yield during both the seasons was maximal in control (110 kg/tree) however, due to good quality fruit during winter season, higher income was obtained with the treated trees as compared to control. Verma and Arha (2004) studied the regulation of flowering in African marigold (*Tagetes erecta* L.) by the application of GA₃ 100, 150 and 200 ppm etherel 250, 500 and 750 ppm, and MH 250, 500, 750 ppm and control. Among all treatment GA₃ 200 ppm recorded maximum flower yield as compared to control.

Effect of foliar application of GA₃, NAA, Ethrel and B-9 on chrysanthemum was studied by (Gautam *et al.* 2006) and observed that GA₃ 200 ppm and NAA 100 ppm increased growth of chrysanthemum flower; however ethrel reduced vegetative growth in all concentration. (Devi *et al.* 2007) studied the effect of gibberellic acid (GA₃ at 50 and 100ppm), NAA (100 and 200ppm) and TIBA (50 and 100ppm) on gladiolus cv. Jacksonville Gola plants were sprayed with gibberellin acid (GA₃, at 50 and 100ppm), NAA (100 and 200ppm) and TIBA (50 and 100ppm) at 4, 6 and 8 weeks after planting of bulbs. NAA at 100ppm (51.96), followed by TIBA at 50ppm (53.00) resulted in the earliest flowering. The growth regulator sprayed at 4 and 6 week after planting recorded earlier flowering than that sprayed at 8 weeks after planting. The longest duration of flowering was recorded at with NAA at 200ppm and 100ppm spray at 6 and 8 week after planting. The minimum spike length (111.31cm) and inter floret length (5.66cm) were recorded with GA₃ at 100ppm sprayed 6 weeks after planting. Tyagi and Singh (2006) reported that spraying of GA₃ (40, 80, 120 and 160 ppm) and IBA (20, 40, 60 and 80 ppm) was done 30 days after planting of tuberose bulb. Significantly longest Vase life (13.85 day) was recorded with 160 ppm GA₃. Effect of GA₃ was significantly superior to IBA as well as control.

Control fruit drop

(Michael F. Anthony *et al.*, 2001) reported that the use of several synthetic Auxin in reducing abscission of mature citrus fruit in California, he found Both NAA and 3,5,6-TPA were effective in controlling preharvest fruit drop in citrus under CA conditions Both materials provided fruit holding late into the harvest season. Yuan, R., and Jianguo, Li.,(2008) studied the effect of different plant growth regulators combination on fruit ethylene production, preharvest fruit drop, fruit quality, and fruit maturation were examined in 'Delicious' apples (*Malus domestica* Borkh.) results showed that 1-MCP or NAA + AVG was more effective than NAA or AVG alone in reducing preharvest fruit drop and extending

the harvest season while maintaining fruit quality. 1-MCP applied 15 DBAH more effectively delayed preharvest fruit drop than when applied 7 DBAH in 'Delicious' apples. 1-MCP more effectively inhibited expression of MdPG2 in fruit abscission zones than AVG alone.

Post-harvest management and Shelf life

(Cronjé, *et al.* 2005) reviewed several plant growth regulators he found that complex plant mechanism is not so readily manipulated and 2,4-D remains the best product to inhibit calyx abscission of citrus fruit. Yuan, (R. *et al.* 2007) studied the effect of various plant growth regulators on fruit ethylene production, preharvest fruit drop, fruit quality, and fruit maturation were examined in 'Golden Supreme' and 'Golden Delicious' apples (*Malus domestica* Borkh.) our results showed that the combinations of NAA (a synthetic auxin) and AVG (an inhibitor of ethylene biosynthesis) or 1-MCP (an inhibitor of ethylene action) was more effective when used in combination than when used alone in reducing preharvest fruit drop and extending the harvest season while maintaining fruit quality.

Relationships between the metabolic and ecophysiological processes

There are several interactions between various ecophysiological and metabolic processes and plant growth regulators that adversely affect the expansion and development of many agricultural crops. Plant biologists now have a much deeper understanding of how hormones influence growth and development because of the identification of receptors for numerous of these hormones (Spartz and Grey, 2008; Pieterse *et al.*, 2009; Simon and Petrák, 2011). In this regard, Dharmasiri *et al.* (2013) describe the results pertaining to these hormonal signalling pathways, highlighting the mechanisms of hormone perception and subsequent signalling pathways that result in the regulation of gene expression. Various hormone groups that differ chemically and structurally control the growth and development of plants. Many strides have been made in the previous few decades towards understanding how these plant hormones are perceived and how they work. All of these hormones are involved in influencing gene expression by either regulating the amount of transcriptional factors or repressors, or their activity through posttranslational changes, even though some hormone responses are not always related to gene regulation. In light of this, ubiquitin-mediated protein degradation has emerged as a key component of numerous plant hormone signalling pathways. In addition, numerous unique signalling mechanisms past ten years have seen the discovery of numerous more plant hormones, including cell wall fragments and peptides (Yamaguchi and Huffaker, 2011; Dharmasiri *et al.*, 2013).

Salicylic acid (SA), jasmonates (JA), and ethylene (ET) are important players and their roles in understanding how plants react to biotic stressors have advanced significantly. A number

of studies suggest that additional hormones, including auxin, gibberellic acid (GA₃), cytokinin, brassinosteroids, and peptide hormones, are also involved in the signalling pathways used by plants to defend themselves (Bari and Jones, 2009). Plant growth-promoting Rhizobacteria (PGPR) have received a lot of interest recently as a potential replacement for agrochemicals (fertilisers and pesticides) for the enhancement of plant growth through a variety of processes. It involves the development of soil structure, the breakdown of organic matter, the recycling of necessary elements, the solubilization of mineral nutrients, the production of numerous plant growth regulators, the degradation of organic pollutants, the stimulation of root growth, essential for soil fertility, the biocontrol of soil and seed-borne plant pathogens, and the promotion of changes in vegetation (Sivasakthi et al., 2014).

Table 1. Plant growth regulators used in horticulture crops for profit

Crops	PGRs	Impact	Reference Citation
Fruits			
Mandarin	2,4-D and NAA	Reduced pre-harvest fruit drop percentage increased fruit weight, juice percentage, total soluble solids, acidity, vitamin C content, and the quantity of fruits per plant.	Nawaz <i>et al.</i> (2008)
Sweet orange	NAA	Maximum improvement in fruit retention, fruit output per plant, fruit production per plant, and fruit drop	Sweety <i>et al.</i> (2018)
Sapota	GA ₃ and NAA	Maximum fruit weight, length, diameter, volume, TSS, reducing and non-reducing sugar, yield per tree, yield per hectare, and prolonged shelf life	Sahu <i>et al.</i> (2018)
	Ethylene	shortened the ripening period and improved the physico-chemical characteristics	Vidhya <i>et al.</i> (2017)
Mango	GA ₃	Slowed down the overall weight loss, the concentration of chlorophyll and ascorbic acid, and the activity of amylase and peroxidase during ripening.	Sahu <i>et al.</i> (2018)
	ABA	Increasing total sugars and sucrose while reducing ruitripene consumption	Zaharah <i>et al.</i> (2012)
	Ethylene	Initiating mango ripening	Nguyen and McConchie (2002)
	Pacllobutrazol	Suppressing vegetative growth, increase flowering, fruit yield and quality	Yeshitela <i>et al.</i> (2004)
Banana	Ethephon (1-MCP)	Delayed ripening process	Xiaoyang <i>et al.</i> (2015)
Guava	GA ₃	Maximum growth, yield, quality attribute and highest germination	Lal and Das (2017)
	BA	Effective in reducing shoot length, shooting response, number of shoots and explants, physiological loss of weight (PLW), decay, reduction in diameter, and juice content	Nagar <i>et al.</i> (2002)
	Ethylene	Increase in the rate of skin yellowing and softening of immature-green fruit	Reyes and Paull (1995)

Custard apple	BA	Enhanced shelf-life	Chouksey et al. (2013)
Pineapple	ABA	Reduced the intensity of internal browning, moisture loss and malic acid content in the crown leaves	Nanayakkara et al. (2005)
Citrus	ABA, Ethylene	Induced callus formation	Goren et al. (1979)
Phalsa	NAA	A higher rate of flowering, fruiting, fruit weight, fruit weight per shoot, fruit juice %, minimum seed percentage, and maximum yield per hectare.	Kacha et al. (2012)
	GA ₃	Increasing vegetative growth and yield	Singh et al. (2017)
Vegetables			
Bitter gourd	NAA	Produced lower sex ratio gave, maximum number of fruits per plant and finally yield per hectare with the maximum BCR	Khatoon et al. (2019)
Capsicum	NAA	Increased plant height, early flowering, number of branches, plant spread, number of flowers per plant, shelf life and TSS	Singh et al. (2017)
Okra	ABA	Enhancing health promoting component	Prajapati et al. (2019)
	IAA	Maximum plant height and intermodal length	Dhage et al. (2011)
	SA and ABA	Significantly reduced the harsh effects of drought on okra germination and growth parameters, enhance the tolerant ability	Baghizadeh and Hajmohammadrezaei (2011)
	CCC	Lowest number of days to first flowering, 50% blossoming, the position of the first flower's node, the maximum number of harvests overall, the number of fruits per plant, yield per plant and per hectare, the weight of a single fruit, the breadth of a fruit, the percentage of Vitamin "A" and crude fibre	Kumar et al. (2018)
	Brassinosteroid	To increase in plant growth and biomass, leaf area, chlorophyll content, photosynthesis rate, photochemical efficiency of PS II	Wajid Khan et al. (2017)
Watermelon	TIBA	Better growth, early flowering, minimum sex ratio, highest fruit yield and superior quality	Chaudhary et al. (2016)
Tomato	2,4-D and IAA	Development of seedless parthenocarpic fruit with increased size, increase growth and yield attributes	Gelmesa et al. (2013) Khaled et al. (2015)
	GA ₃	For yield attribute	Sharma et al. (2018)
	Ethylene	Promotion of fruit ripening, flowering and overall plant growth	Sunidhi and Gandhi, 2019
	Cytokinin	Breaking dormancy after seed imbibition, also allowing germination and growth of dormant embryos.	Nawaz et al. (2012)
	PBZ	Improves the photosynthetic activity and water balance	Berova and Zlatev (2000)
	Thiourea	Increased plant dry weight and the tomato yield after inoculation	Nasr A. (1993)
Onion	NAA	Reduced physiological loss of weight, spoilage loss	Patel et al. (2010)
Brinjal	NAA	Long-styled flower percent, number of fruits/plant, and the highest fruit yield	Moniruzzaman et al. (2014)
Pea	GA ₃	Maximum number of pods per plant, seed yield, seed index and protein content in seeds	Bora and Sarma (2006)
Pumpkin	GA ₃	Enhancing growth and yield	Sure et al. (2012)
Bottle gourd	GA ₃	Maximum fruit length, fruits weight and fruits girth	Kumari et al. (2019)
Cucumber	GA ₃	maximum fruit set percentage, fruit retention and TSS	Kadi et al. (2018)
	Ethylene	Induce femaleness	Rudich et al. (1969)
Muskmelon	Potassium nitrate	TSS, carotene, ascorbic acid, thickness of the flesh, hardness of the fruit, skin colour, moisture content, and shelf life are examples of quality characteristics.	Sindhuja et al. (2017)
	CPPU	Increase number of fruits per vine, fruit weight and yield per vine	Sindhuja et al. (2017)
Lettuce	ABA	Minimize the effects of drought stress	Al Muhairi et al. (2016)
Cluster bean	SA and Thiourea	Higher yield parameters, yield and gum content	Meena and Meena (2017)
Flowers			
	NAA	Greater amount of carbohydrate accumulation and increased metabolic activities	Khudus et al. (2017)

Calendula	SA	Increased CO ₂ assimilation and photosynthetic rate and increased mineral uptake	Bayat <i>et al.</i> (2012)
<i>Clerodendrum splendens</i>	IBA	Increase in sprout length and root length	Jamal <i>et al.</i> (2015)
Orchid	NAA	Enhanced the plant growth and development	Khandaker, M. M. <i>et al.</i> (2016)
Rose	IBA	Increase survival percentage, maximum number of roots and the longest roots	Susaj <i>et al.</i> (2012)
Marigold	NAA	Maximum weight and diameter of fully opened flower	Meshram <i>et al.</i> (2015)
	GA ₃	Increase vegetative growth and flowering	Mishra (2017)
	CCC	Increased flower yield and number of flowers/plant	Kumar <i>et al.</i> (2011)
	Triacantanol	Increase plant height, number of laterals, number of leaves and leaf area	Muruganandam (2014)
Chrysanthemum	GA ₃	Increase plant height, number of branches, suckers, leaves plant ⁻¹ , leaf area, days to flower and number of flowers	Sajid <i>et al.</i> (2016)
Gladiolus	GA ₃	Increase plant growth and flowering attributes	Reshma <i>et al.</i> (2017)
	ABA	As a hormonal trigger in ethylene insensitive senescence process	Kumar <i>et al.</i> (2014)
	Ethrel	Increased corm splitting, delayed flowering and slightly shortened flower stems	Halevy <i>et al.</i> (1970)
	SA	Improves vase life	Rahmani <i>et al.</i> (2015)
	BA	Sprouting of multiple buds and increase production of corms	Sajjad <i>et al.</i> (2015)
Tuberose	GA ₃	Beneficial for sprouting	Ganesh <i>et al.</i> (2013)
China aster	GA ₃	Increase number of primary branches, flower yield per hectare, seed yield per plant and seed yield per hectare	Kumar <i>et al.</i> (2015)
	SA	Increased growth, flower and seed yield	Kumar <i>et al.</i> (2015) [48]
Matthiola incana	Kinetin and NAA	Shoot length, greatest number of nodes and highest length of roots	Hesar <i>et al.</i> (2011) Kaviani <i>et al.</i> , 2013
Cactus	ABA	Increase in calli fresh weight and colour	Lema-Ruminska <i>et al.</i> (2013)
Petunia	Ethylene	Induced adventitious root formation	Dimasi-Theriou <i>et al.</i> (1993)
Gerbera	BA and GA ₃	Increase vase life, fresh weight, solution uptake, membrane stability and TSS	Danaee <i>et al.</i> (2011)
Dahalia	MH	Highest number of flowers and diameter of bud	Malik <i>et al.</i> , (2017)

In the context of 'green' biotechnologies for tree fruits, such as plant breeding, the new technologies have lately emerged as potent instruments. Use of plant regulators and hormonal plant regulation are two further examples of innovative technologies. In salt-stressed and control *Arabidopsis thaliana* seedlings Costa *et al.* (2017). Simura *et al.* (2018) established the validity of and made a hormonomic approach (including quantification of the main phytohormone classes or groups: cytokinins, auxins, brassinosteroids, gibberellins, jasmonates, salicylates, and abscisates).

In vitro plant tissue culture

Regardless of the plant species, PGR usage is a crucial procedure in plant tissue culture.

According to Perera *et al.* (2009), consistent callogenesis was produced by cultivating unfertilized ovaries at the -4 stage in CRI 72 medium containing 100 M 2, 4-D and 0.1% activated charcoal. They also examined the impact of plant growth regulators on the ovarian

culture of the coconut (*Cocos nucifera* L.). Application of 9 M TDZ improved callus development. On somatic embryogenesis induction media containing 66 M 2, 4-D, embryogenic calli were subcultured. The somatic embryos' growth was stunted after being subcultured onto CRI 72 media containing ABA. In Y3 medium, somatic embryo maturation was possible without the use of growth regulators. While 2-isopentyl adenine (2iP) improved the frequency of plant regeneration, adding GA3 to conversion solution containing 5 M BA stimulated the conversion of somatic embryos. Garcia et al. (2011) found that the direct organogenesis in this species was obtained through shoot development from internodal segments in the presence of BA in an in vitro study examining the effects of explant type, plant growth regulators (NAA, picloram - PIC, and 2, 4-D), salt composition of basal medium, and light on callogenesis and regeneration in *Passiflora suberosa* L. (passion fruit - Passifloraceae). On media containing BA as a supplemental ingredient, either by itself or in combination with NAA, indirect organogenesis was accomplished from all explant types.

Conclusion

With the help of reviews mentioned above it is concluded that the application of several plant growth regulators in horticultural crops will continue to increase in the near future, depending primarily upon the economic benefits of this technique in comparison to other production Methods. It will continue to have applications as horticultural crops as well as many Agricultural crops on established plant propagation, Breaking of Seed dormancy and seed germination, enhancing and regulation of flowering, controlling flower drop, Fruit thinning, Fruit Setting and Parthenocarpy, Post-harvest management and extending shelf life of horticultural crops. A growing trend in horticulture with many benefits is the use of plant regulators. The method used to apply plant growth regulators exhibits good outcomes in horticulture. The conclusion that the application of plant growth regulators in horticulture plants can be a challenge for all those who act in the sector, presenting practical advantages and favourable possibilities for future use, leads to additional studies, weights, and conversations on the subject. The integration and coordination of several signalling events during plant growth is necessary for the regulation of complicated growth and developmental processes. PGRs would be advantageous as an excellent method for producing the variety of horticulture plants in nurseries, fields, and greenhouses. Today's world requires a high output yield, improved crop production, and the incorporation of new technologies. In order to further our understanding of plant physiology, future horticultural research will be dependent on the development of molecular and biotechnological methodologies. This is especially true for research on the use of plant growth regulators in horticultural plants. The use of plant

growth regulators for additional high value crops, such as vegetables, fruits, and flowers, should be investigated for novel options. Applying these substances might be a good strategy to lessen the damaging effects of stress on plant growth. The crops of several horticultural plants can also benefit from the alteration of the hormonal balance. In the context of biotechnologies, the new technologies have recently come into their own as potent tools. The use of plant regulators and hormonal plant regulation is also emphasised as innovative technology. Horticultural advancements in science and technology are without a doubt essential to achieving success in one's endeavours. We now have the instruments necessary for using plant hormones and plant growth regulators (PGRs) in horticulture and agriculture thanks to the rapid advancement of technology.

Future perspectives

Future prospects for plant growth regulator use and application in agriculture look bright, particularly when it comes to horticultural crops. Understanding how the information transmitted by these straightforward chemicals is incorporated throughout plant growth would be a significant task (Santner et al., 2009). In addition, during the past few years, it has become clearer the molecular mechanisms governing hormone synthesis, signalling, and action, as well as the functions of plant hormones in adapting to environmental changes. The alteration of hormone biosynthesis pathways to produce transgenic plants with improved biotic stress tolerance will be made easier by these discoveries. It has been discovered that either synthetic or natural crop growth controllers are more effective and thorough at boosting crop production. They can also, when used sparingly, cause rapid changes in plant phenotypes and support plant growth by either improving or reviving the growth control system or by accelerating seed purification and licencing. If you consider how well they perform overall in all facets of plant growth, even a slight increase of 10–15% can result in an increase in total yearly yield of 10–15 million tonnes. Plant growth regulators (PGRs) are economically significant in numerous ways for the agriculture industry. Growth control is also used frequently in the generation of hybrid seeds, inflorescence spraying, and seed resistance to pests and diseases in vegetables.

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