Role of plant growth regulators in ornamental plants

Sachin T. M., Homraj Sahare

Department of Horticulture, School of Agriculture, Lovely Professional University, Jalandhar-Delhi G.T. Road (NH-1), Phagwara, Punjab, India-144411.

Abstract

Ornamental plants play a vital role in the global horticultural industry. Plant growth regulators are a wide group of naturally occurring or synthetically generated organic chemicals that are used as a commodity in the industrial ornamental production system. Plant growth regulators have a faster effect on flowering crop yields, both vegetative and flowering. The use of growth regulators in ornamental crops must be selective, non-toxic, and environmentally friendly. Their exogenous application contributes to the enhancement of various economically significant and market attractive characteristics of ornamental plants. As a cultural practice, commercial ornamental plant producers use plant growth regulators. The physiological processes of flowering crops are affected by plant growth regulators, followed by the development and flower formation of flowering crops affected by plant growth regulators. The types of plant growth regulators and their effects on ornamental plants are discussed in this review.

Keywords: Ornamental, Plant growth, growth regulators, production.

Introduction

The ornamental industry is primarily focused on the planting of foliage and flowering plants suitable for growing in beds and pots. The commercial cultivation of ornamental plants is growing all over the world. Cut leaves, cut trees, bedding plants, indoor plants, potted plants, bulbous plants, and outdoor plants are all examples of ornamental plants, which may be annuals, biennials, or perennials depending on their growing habits. As a result, ornamentals add artistic value to our surroundings (Riaz *et al.*, 2002; Noor-un-Nisa *et al.*, 2013). and there has been a growth in the market for ornamental plants for personal and ritual purposes. Cut flowers are the most common ornamental plants, followed by flowering pot plants, tree and nursery plants, and flower bulbs (Lawson, 1996), but this is no longer the case. and is also commercially significant in the global horticultural trade. Humans have even used them in the past, also in ancient times (Simpson and Ogorzaly, 2001). For commercialization and conservation of the floriculture industry, we need a technical approach and proper management practices, such as quality improvement of flower germplasm, proper fertilizer management, high-tech processing technology, good seeds and planting material, precision farming, and so on (Wani *et al.*, 2017). For growing ornamental crop yield and maintaining it at a high level, we need integrated nutrient management (Kumar and Chaudhary, 2018). Following the invention of plant growth regulators, there has been a considerable shift in agriculture, especially in floriculture. The use of plant growth regulators produces a better outcome in floriculture development. Plant growth regulators have been investigated to increase the number of flowers and regulate flowering according to farmer needs.

Development in a plant is the result of cell division, enlargement of new cells, and differentiation into various types of tissues; these growth processes are followed by a permanent change in size [usually an increase in length or volume]. In addition, the dry weight of the growing parts increases.

Types of Plant Growth

1. **Primary and Secondary Growth -** The meristematic cells present at the root and shoot apices divide mitotically and increase the length of the plant body. And Secondary Growth is referred to as the increase in the diameter of the plant body by the division of the Secondary meristem.
2. **Unlimited Growth -** When the plant constantly grows from the germination stage to death is known as Unlimited Growth.
3. **Limited Growth -** In this stage, the plant parts stop growing after attaining a certain size.
4. **Vegetative Growth -** It involves the production of stem leaves and branches except for the flowers.

5. **Reproductive Growth -** Flowering occurs at this type of growth stage.

Growth regulators are chemicals that naturally occurring in plant tissues (i.e., endogenously), have a nutritional role rather than regulatory in growth and development. These chemical compounds generally active at very low concentration are known as plant hormones (or plant growth substances) and these substances are produced synthetically they are called plant growth regulators (PGR). (Rademacher 2015). In various are of agriculture plant growth regulators used for increasing production with better phytochemical, phytosanitary and commercial quality. In the world for one million hectares land plant growth regulators are used However, most of these applications are confined to high valve horticultural crops rather than field crops. Plant growth regulators applied foliar can help increase fruit and cut flower quality parameters (Khalid *et al.*, 2012).

Plant growth regulators (PGRs) or phytohormones are organic compounds other than nutrients that are naturally formed in higher plants that regulate growth or other physiological functions at a location distant from their source of origin. They are active in minute quantities and alter plant physiological processes. Bio-stimulants and bio-inhibitors are PGRs that function within plant cells to activate or inhibit certain enzymes or enzyme systems, thus assisting in the regulation of plant metabolism. They are usually active in plants at very low concentrations. PGRs were first recognized in the 1930s for their significance. Natural and synthetic compounds have been discovered since then that changes the function, form, and size of crop plants. PGRs are now used to alter crop growth rate and pattern at different stages of production, from germination to harvest and post-harvest storage. Growth-regulating chemicals that have a favourable impact on large agronomic crops may be beneficial.

Based on their actions plant growth regulators are broadly classified into two major groups.

- **Plant growth promoters**
- **Plant growth inhibitors**

Plant growth promoters – The plant bioregulators or hormones which have catalytical effects i,e. vital responsible in plant growth are called growth promoters. Auxin, Gibberellins, and Cytokinines are grouped into plant growth promotors.

Auxins

These are a group of phytohormones synthesis in the shoot and root apices and they transfer from the apex to the elongation zone. Auxins promote longitudinal axis growth of the plant hence it is called auxeing (to grow or to increase). Auxins are found in abundance in the developing tips of the plant, such as the coleoptile top, buds, root tips, and leaves. The only naturally found auxin in plants is Indole Acetic Acid (IAA). They (auxin) promote growth at low concentrations while inhibiting growth at high concentrations. They are known for inducing plant cell enlargement and stem elongation. They are also involved in the growth of plant branches and are linked to apical domination. As a result, an auxin can be described as an organic material that, when added in low concentrations to shoots of plants that have been released as far as possible from their intrinsic growth-promoting substances, promotes growth (i.e., permanent growth) along the longitudinal axis. Auxins can have other properties, as they usually do, but this one is crucial (Thimann, 1963). Previously, auxins were thought to have only one function: to stimulate cell elongation. However, subsequent research has shown that they are intimately linked to a wide range of functions.

The synthetic auxins include

- IBA: Indole Butyric Acid
- NAA: Naphthalene Acetic acid
- MENA: Methyl ester of Naphthalene acetic acid
- MCPA: 2 Methyl 4 chlorophenoxy acetic acid
- TIBA: 2, 3, 5 Tri iodo benzoic acid
- 2, 4-D: 2, 4 dichloro phenoxy acetic acid
- 2, 4, 5-T: 2, 4, 5 Trichloro phenoxy acetic acid

Application of auxin in ornamental crops

Auxin is well known for promoting cutting rooting (Hartmann *et al.*, 2002). IBA is the auxin that is most commonly used for commercial rooting (Nickel, 1990). Auxins play an important role in regulating plant growth and development; they also affect the formation of primary, secondary, and adventitious roots, among other things (Sebanek, 2008). The naturally occurring auxin in plants is indole acetic acid (IAA). Synthetic 3-indole butyric acid (IBA) is the most widely used auxin, and when compared to natural indolyl-3-acetic acid (IAA), it is the most powerful hormone for promoting adventitious root development (Pop *et al.*, 2011). The transfer of IBA to IAA in plant tissue promotes rooting. In carnation cuttings treated with IBA, rooting percentage and other rooting parameters improved significantly across cultivars (Gowda *et al.*, 2017). In carnation cuttings, auxins were also effective regulators in inducing rooting and reducing the number of days needed for rooting (Singh *et al.*, 2006). The effects of various auxins and their concentrations on marigold rooting parameters increased rooting percentage, root length, root number, and root dry weight (Sharma 2014). The application of IBA + NAA 150 ppm to marigold tip cuttings resulted in a substantial rise in the number of roots (58.79) and the longest root/cutting interval (Bhatt *et al.*, 2012). The most primary and secondary roots per cutting, the longest root length, the freshest weight of roots per cutting, and the most leaves per cutting were all included in IBA-treated poinsettia cuttings (Singh and Singh, 2005). Early root presence (22.55 day) with maximum rooting (76.67 percent), largest primary root number (12.57), longest root (5.87 cm), and field survival (73.13 percent) in cuttings treated with IBA @ 1500 ppm in a commercial cut flower cultivar of rose called ‘First Red' when treated with indole butyric acid (IBA) and naphthalene acetic acid (NAA) (Dawa *et al.*, 2013). Auxins were used to boost rooting parameters in roses, and they had a big effect (Akhtar et al., 2015). Hatamzadeh *et al.*, (2012) looked at the impact of salicylic acid (SA) on the quality and vase life of cut Gladiolus cv. “Wings Sensation” flowers at four stages of growth (bud stage; half bloom; full bloom; senescence). SA concentrations of 50, 100, 150, and 200 mg/L were used to prepare the flowers. The SA delayed flower senescence and ion leakage in petals, as well as fresh weight loss and lipid peroxidation, according to the findings. Auxin not only plays a vital role in defining floral organ roles but also controls floral meristemic cell proliferation, as seen by the occurrence of a new gynoecium on top of an existing gynoecium (Cheng *et al.*, 2006). Exogenous auxins improve rooting efficiency and stem cutting accuracy, while IBA and NAA promote adventitious rooting in cuttings (Copes and Mandel, 2000).

Gibberellins

Gibberellins (GA) are important plant regulators that control seed germination, stem elongation, leaf expansion, pollen maturation, and flowering induction, among other processes. The ent-gibberellane structure gives gibberellins their name. Gibberellic acid was the first gibberellin to be identified. Gibberellins are produced by a range of species, ranging from fungi to higher plants, and there are over 100 different types. As a result, GA-deficient mutant plants have a dwarf phenotype and flower late; treating these plants with GA restores normal development. Because of its beneficial effect on plant growth and production, gibberellic acid (GA3) is a natural plant regulator with numerous applications in agriculture and horticulture. It has been shown to improve seed germination (Lee *et al.*, 2016, Urbanova and Leubner-Metzger, 2018), shorten the juvenile process, leaf expansion and growth, stem elongation (Oh *et al.*, 2015 and Oh *et al.*, 2014), and early flowering in a variety of crops and ornamental plants (Wilkie *et al.*, 2008). Growing demand for patterned foliages and cut-flowers with long vase lives has prompted researchers to create new protocols to meet industry demands. GA3 foliar applications increased flower stem length (Bergmann *et al.*, 2016) and delayed leaf yellowing in cut flowers grown in the field (Toscano *et al.*, 2018). Gibberellins are found in all parts of the plant, including the leaves, stems, roots, seeds, embryos, and pollen. The reproductive tissues, on the other hand, have a high concentration of gibberellin, while the roots have a lower concentration (Coll *et al.*, 2001).

Applications of gibberellins in ornamental crops

GA 3 is used to increase the number of flower buds, seeds, and inflorescences in floriculture (da Silva Vieira *et al.*, 2010). Gibberellins are involved in a variety of plant developmental processes, including promoting leaf area, flower stalk elongation, early and uniform flowering, and increased flower size (Al-Khassawneh *et al.*, 2006). Zulfiqar *et al.*, 2019 reported tuber grew better at a concentration of 150 mg/L, while the radicle grew best at a control concentration. The seeds did not germinate at a concentration of 50 mg/L. At 100 mg/L GA3 concentrations, similar findings in terms of leaf area and plant height were observed in Gazania rigens L (treasure flower). Aparna *et al.*, 2018 mentioned that under short-day conditions, higher GA3 concentrations

(200 mg/L, 300 mg/L, and 400 mg/L) improved the vegetative development of Chrysanthemum morifolium cv. Thai Chen Queen (florist's daisy). Seven Pelargonium (geranium) cultivars had their root systems treated with four concentrations of GA3 (0.05, 0.5, 5.0, or 50 mg/L). As the concentration of GA3 increased, the relative growth rate of all cultivars studied improved. Each cultivar's root-to-shoot ratio decreased in tandem with their increased growth rate (Arteca *et al.*, 1991). Huang in 2007 demonstrated that 5 mg/L GA3 induced flowering in Kalanchoe pinnata (Goethe plant) and Kalanchoe poincarei (alligator plant) plants. In addition, Emami *et al.* (2011) found that GA3 in conjunction with benzyl adenine improved the chlorophyll content of lily leaves. In rhododendron (*Rhododendron pulchrum*), Chang and Sung (2000) found that GA3 had an impact on the growth of buds and flowers per plant, showing the colours of the buttons 10 days before flowering and anticipating flowering in nine days compared to the control. Pre-treatment with GA3 at a concentration of 83 mg/L was useful for the development of seedling serum by rhizomes due to the formation of trees of greater height (Tavares and Almeida, 2005). This result was also seen in the chrysanthemum 'Gompier-cha', where 100 mg L-1 was applied to plants grown in greenhouses (pot) and the vase life was extended by 16 days relative to untreated controls (Freitas, 2001). According to Ramesh *et al.* (2001), the application of gibberellic acid @ 150 ppm resulted in the maximum plant height (75.10 cm) in china asters, while Maleic Hydrazide @1500 ppm resulted in the largest number of branches per plant (13.15). Singh *et al.,* (2013) investigated the effects of GA3 on gladiolus cultivar growth and flowering characteristics. On the cvs. Sabnum and Gunjan, the overall length of the leaf and the width of the longest leaf were registered with GA3 at 400 ppm. At 200 ppm GA3, cv. Gunjan produced the highest number of leaves per vine, when GA3 was sprayed at higher concentrations, early spike emergence was observed among flowering parameters in cv. Sabnum (300-400 ppm). The maximum length of spike was achieved with GA3 at 300 ppm, while the maximum number of florets per spike was achieved with cv. Snow Princess when GA3 was added at 100-200 ppm. Duration and number of treatments investigated had only a minor effect on the growth and production of *Ajania pacifica* when exogenous GA3 was applied at concentrations (Zalewska and Antkowiak, 2013). An experiment was carried out by Bose *et al.* (2003) to investigate the impact of GA3 on gladiolus cv. 'Erovision' flowering and consistency characteristics. Corms were soaked in 0 (control), 50, and 100 ppm GA3 solutions for 1 hour before being planted at 49 corms/m2 five days later; GA3 at 100 ppm reduced the time between planting and harvesting and increased flowering percentage, spike weight, flower number per spike, and flower stem diameter. Ranwala and Miller (2002) found that spray or pulse treatments with gibberellins inhibited leaf chlorosis in Asiatic lily hybrids, with GA4+ GA7 being more successful than GA3.

Cytokinins

In the production of many industrial plant growth regulators, cytokinins have a great significance (Padhye *et al.,* 2008). The term cytokinins refer to all naturally occurring compounds that have been shown to stimulate cell division. Letham coined the phrase "cytokinin" (1963). They are also believed to postpone the onset of senescence. The first naturally occurring cytokinin, known as zeatin, was discovered in rice. Cytokinins are also known as phytokinins. Synthetic benzyl adenine and kinetin are the most commonly distributed cytokinins. The chemical compound 6-furfuryl aminopurine was found in the tobacco pith callus and called kinetine. Cytokinins are called natural plant growth hormones because they primarily influence cell division and growth. The apical root meristem, inflorescences, and emerging fruits tend to be the primary sources of natural cytokinin. They also promote seed germination and uniform flowering. Cytokinins regulate metabolite transfer in the phloem. Cytokinins are also useful in the protection of flowers, seeds, and leafy vegetables. Cytokinins, when applied externally, stimulate the development of lateral buds and thereby counteract the influence of apical dominance.

Application of cytokinins in ornamental crops

Use of cytokinins in ornamental plants Cytokinins have been used for ornamental plants on many occasions, although the concentration of cytokinins that are beneficial differs between ornamental plants (Werbrouk *et al.,* 1996). Many plants, including the Dendrobium orchid (Sakai *et al.*, 1998), Lilium (Ohkawa, 1978), and Achimenes longiflora, have shown positive effects of cytokinins (Vlahos, 1985). Nicola *et al.* (2010) experimented and confirmed that a combined treatment of cytokinin and gibberellic acid at 100ppm and 200ppm, respectively, prevented leaf chlorosis and senescence in the Compositae family plants as compared to control plants. However, Yadav *et al.* (2015) stated that using cytokinin at 200 ppm resulted in the highest stem diameter, fresh weight of flower, shortest days to seed ripening, and highest seed yield in marigold as compared to other stages. The study of hormones, proteomes, and transcriptomes also reveals that cytokinin plays an important role in plant tolerance to heat stress, with increased cytokinin upregulating much of the heat shock (HS) reaction proteins (Shalak *et al.,* 2016). In shoot growth, cytokinin is a positive regulator, while in root development, it is a negative regulator (Werner *et al.*, 2003). Since roots are a major source of cytokinins, which have been shown to facilitate bud break in roses (Mor and Zieslin, 1987), cytokinin activity in young root tips may be a key factor in axillary bud sprouting. Benzyl aminopurine is an essential cytokinin, and according to Bonhomme *et al.* (2000), cytokinins play an important function in the initiation of the flowering process in plants. The argument is confirmed further by the observations of Nguyen et al. (2006), who discovered that using cytokinin will help increase the percentage of rose plants that bloom. Richmond and Lang (1957) investigated Xanthium and discovered that Cytokinin would delay senescence for many days. In certain plants, cytokinins increase susceptibility to high temperatures, frost, and diseases. Cytokinin also aids flowering in photoperiodic conditions that are unfavourable. They stimulate the synthesis of certain photosynthesis-related enzymes in some situations.

Plant Growth Inhibitors - Growth Inhibitors are plant bio-regulators that selectively interfere with natural hormonal growth promotion, such as Abscisic acid and Ethylene.

Abscisic acid (ABA)

They were historically known as Dormin or Abscisin primarily because of their regulatory impact on dormancy and abscission. This hormone is widely distributed in higher plants and can be present in a variety of organs and tissues (both old and young). ABA causes the leaves of a wide range of plants to abscise, as well as the fruits of certain plant species. Abscisic acid (ABA) has long been known to play a key role in drought, osmotic, and high salinity reactions, and is thus often referred to as a stress hormone (Zhang, 2014). One of the best-studied mechanisms of action of ABA in response to drought stress is the regulation of transpiration by stomatal opening and closing (Li *et al.*, 2020). Abscisic acid (ABA), a plant hormone, plays a part in plant responses to environmental pressures, and ABA applications reduce water loss and improve drought tolerance (Leskovar and Cantliffe, 1992; Yamazaki *et al.*, 1995). The use of chemical products in floriculture plants to mitigate water loss has produced variable effects. However, modern ABA formulations are now available as plant growth regulators to commercial producers (Barrett and Campbell, 2006).

Application of abscisic acid in ornamental crops

In the floriculture sector, drought stress is a significant cause of postproduction shrinkage (Barrett and Campbell, 2006). For all treated bedding plants ABA applications contributed to a reduction in water loss during serious drought stress. Exogenous ABA treatment during the spring/summer growing season decreases respiration and water loss in potted miniature roses (Rose hybrida L.) and increases flower lifespan (Monteiro *et al.*, 2001). Leaf chlorosis was observed on s-ABA-treated pansies, according to Blanchard *et al.* (2007), but there was no quantification of the magnitude of the reaction, and no evidence was given for non-drought-stressed plants treated with sABA. Leaf chlorosis in pansies may be due to increased synthesis or exposure to other senescence-related hormones, such as ethylene. Exogenous ABA has been shown to increase ethylene content while decreasing cytokinins, resulting in leaf senescence (Taiz and Zeiger, 2002).

Ethylene

This is a basic gas released in limited amounts by many plant tissues, and it acts as a powerful growth and development regulator. Ethylene is produced naturally in plants in large quantities to have regulatory implications, and it may be classified as a plant hormone. They are abundant in physiologically matured fruits that are about to ripen. When added to plants, synthetic chemicals such as etherel, ethephon, and chloroethyl phosphonic acid (CEPA) have been shown to release ethylene. Breaking dormancy, inducing abscission of leaves, and inhibiting elongation and lateral bud development are all essential functions of ethylene in plants.

Application of Ethylene in ornamental crops

According to Umrao *et al.*, (2006), 500 ppm ethrel provided substantially more sprouts per corm of gladiolus than lower and higher doses, as well as a control. Ethrel 1500 ppm took a minimal number of days to sprout (20.23), while untreated corms took the maximum numbers of days to sprout (25.33), and earlier flowering took place (87.87d) while blooming, whereas untreated corms took the maximum numbers of days observed in gladiolus (Bhalla and Kumar, 2007). According to Kumar and Singh (2005), the length of the spike decreased linearly as ethrel concentrations increased. Umrao *et al.*, (2006) found that the weight of gladiolus corm decreased linearly with increasing ethrel concentration, with the higher dose (750 ppm) resulting in a lighter corm (38.01 g) than the control (38.95 g), but the lower dose (250 ppm) resulting in a heavier daughter corm (40.91 g) than the control.

Conclusion

Through using various plant growth regulators to improve the physiological activities of ornamental plants, they can be cultivated all year long with desirable consistency. It is involved in the metabolism and distribution of solutes within the plant. Methods that will be pre-planting or subsequent spraying on the plant can be used in a developing area according to acceptability. Development regulators, especially for horticulture plants, have become an important part of cultivation practices. There are a variety of plant growth regulators available that can be used for a variety of purposes such as improve the germination time, increasing plant height, increasing self-life, producing more corms and bulbs per plant, reducing crop period, and so on, and they are ideal for use in different regions of the world.

Reference

Akhtar, G., Akram, A., Sajjad, Y., Balal, R. M., Shahid, M. A., Sardar, H., ... & Shah, S. M. (2015). Potential of plant growth regulators on modulating rooting of Rosa centifolia. *American Journal of Plant Sciences*, *6*(05), 659.

Al-Khassawneh, N. M., Karam, N. S., & Shibli, R. A. (2006). Growth and flowering of black iris (Iris nigricans Dinsm.) following treatment with plant growth regulators. *Scientia Horticulturae*, *107*(2), 187-193.

Aparna, V., Prakash, K., Neema, M., Ajay, A., Kumar, N., & Singh, M. C. (2018). Effect of Gibberellic Acid on plant growth and flowering of Chrysanthemum cv. Thai Chen Queen under short day planting conditions.

Arteca, R. N., Schlagnhaufer, C. D., & Arteca, J. M. (1991). Root applications of gibberellic acid enhance growth of seven Pelargonium cultivars. *HortScience*, *26*(5), 555-556.

Barrett, J., & Campbell, C. (2006). S-ABA: Developing a new tool for the big grower. *Big Grower*, *1*(4), 26-29.

Bergmann, B. A., Dole, J. M., & McCall, I. (2016). Gibberellic acid shows promise for promoting flower stem length in four field-grown cut flowers. *HortTechnology*, *26*(3), 287-292.

Bhalla, R., & Kumar, A. (2007). Response of plant bio-regulators on dormancy breaking in gladiolus. *Journal of Ornamental Horticulture*, *10*(4), 215-221.

Bhatt ST, Chauhan NM, Patel GD. Effect of auxin on rooting of tip cutting in African marigold. Green Farming. 2012; 3(4):121-124.

Runkle, E. S., Woolard, D., Campbell, C. A., Blanchard, M. G., & Newton, L. A. (2007, December). Exogenous applications of abscisic acid improved the postharvest drought tolerance of several annual bedding plants. In *International Conference on Quality Management in Supply Chains of Ornamentals 755* (pp. 127-133).

Bonhomme, F., Kurz, B., Melzer, S., Bernier, G., & Jacqmard, A. (2000). Cytokinin and gibberellin activate SaMADS A, a gene apparently involved in regulation of the floral transition in Sinapis alba. *The Plant Journal*, *24*(1), 103-111.

Bose, T.K., Yadav, L.P.; Pal, P.; Pathasarathy, V.A.; Das, P. 2003. Chrysanthemum Commercial Flowers. Vol-1. 2nd Rev. ed. Nayaprokash, Calcutta, India, pp. 463-602

Chang, Y. S., & Sung, F. H. (2000). Effects of gibberellic acid and dormancy-breaking chemicals on flower development of Rhododendron pulchrum Sweet and R. scabrum Don. *Scientia horticulturae*, *83*(3-4), 331-337.

Cheng, Y., Dai, X., & Zhao, Y. (2006). Auxin biosynthesis by the YUCCA flavin monooxygenases controls the formation of floral organs and vascular tissues in Arabidopsis. *Genes & development*, *20*(13), 1790-1799.

Coll JB, Rodrigo GN, Garcia BS, Tamés RS (2001). In: Fisiología Vegetal. Madrid: Ediciones Pirâmide. p. 566.

Copes, D. & Mandel, N. (2000). Effects of IBA and NAA treatments on rooting Douglas-fir stem cuttings. New Forests. 20. 249-257.

da Silva Vieira, M. R., Citadini, V., Lima, G. P. P., de Souza, A. V., & de Souza Alves, L. (2010). Use of gibberellin in floriculture. *African Journal of Biotechnology*, *9*(54), 9118-9121.

Dawa, S., Rather, Z. A., Sheikh, M. Q., Nazki, I. T., & Hussain, A. (2013). Influence of growth regulators on rhizogenesis in semi-hardwood cuttings of some cut flower roses. *Applied Biological Research*, *15*(2), 1-7.

Emami, H., Saeidnia, M., Hatamzadeh, A., Bakhshi, D., & Ghorbani, E. (2011). The effect of gibberellic acid and benzyladenine in growth and flowering of Lily (Lilium longiflorum). *Advances in Environmental Biology*, 1606-1612.

Freitas ST (2001). Aplication of gibberellic acid Field in the vase life of chrysanthemum cv. 'Gompier-cha'. In: Mostra de Iniciação Cientifica, Cachoeira do Sul. Anais... Cachoeira do Sul: ULBRA. 4: p. 184.

Gowda, P., Dhananjaya, M. V., & Kumar, R. (2017). Effect of indole butyric acid (IBA) on rooting of different carnation (Dianthus caryophyllus L.) genotypes. *Int. J. Pure Appl. Biosci*, *5*, 1075-1080.

Hartmann HT, Kester DE, Davis JFT, Geneve RL. Plant propagation: principles and practices. New Jersey: Prentice Hall. 2002: 880. ISBN 0-13- 679235-9.

Hatamzadeh, A., Hatami, M., & Ghasemnezhad, M. (2012). Efficiency of salicylic acid delay petal senescence and extended quality of cut spikes of Gladiolus grandiflora cv wings sensation. *African Journal of Agricultural Research*, *7*(4), 540-545.

Huang, C. H. (2007). *Studies on Flowering Physiology, Interspecies Hybridization and ISSR Analysis of Kalanchoe Species Native in Taiwan* (Doctoral dissertation, Ph. D. Thesis, National Chung Hsing University, Taichung, Taiwan).

Khalid, S., A.U. Malik, A.S. Khan and A. Jamil, 2012. Influence of exogenous applications of plant growth regulators on fruit quality of young 'kinnow' mandarin (Citrus nobilis × C. deliciosa) trees. Int. J. Agric. Biol. 14:229-234.

Kumar, M., & Chaudhary, V. (2018). Effect of integrated sources of nutrients on growth, flowering, yield and soil quality of floricultural crops: A Review. *International Journal of Current Microbiology and Applied Sciences*, *7*(3), 2373-2404.

Kumar, V., & Singh, R. P. (2005). Effect of soaking of mother corms with plant growth regulators on vegetative growth, flowering and corm production in gladiolus. *Journal of Ornamental Horticulture*, *8*(4), 306-308.

Lawson, R. H. (1996). Economic importance and trends in ornamental horticulture. In *IX International Symposium on Virus Diseases of Ornamental Plants 432* (pp. 226-237).

Lee, J. W., Kim, Y. C., Kim, J. U., Jo, I. H., Kim, K. H., & Kim, D. H. (2016). Effects of gibberellic acid and alternating temperature on breaking seed dormancy of Panax ginseng CA Meyer. *Korean Journal of Medicinal Crop Science*, *24*(4), 284-293.

Leskovar, D. I., & Cantliffe, D. J. (1992). Pepper seedling growth response to drought stress and exogenous abscisic acid. *Journal of the American Society for Horticultural Science*, *117*(3), 389-393.

Li, S., Li, X., Wei, Z., & Liu, F. (2020). ABA-mediated modulation of elevated CO2 on stomatal response to drought. *Current Opinion in Plant Biology*, *56*, 174-180.

Noor-un-Nisa, M., Qasim, M., Jaskani, M. J., Khooharo, A. A., Hussain, Z., & Ahmad, I. (2013). Comparison of various explants on the basis of efficient shoot regeneration in gladiolus. *Pak. J. Bot*, *45*(3), 877-885.

Monteiro, J. A., Nell, T. A., & Barrett, J. E. (2001). Postproduction of potted miniature rose: Flower respiration and single flower longevity. *Journal of the American Society for Horticultural Science*, *126*(1), 134-139.

Mor, Y., & Zieslin, N. (1987). Plant growth regulators in rose plants. *Hort. Rev*, *9*, 53-73.

Nguyen, H.V., H.A. Phan and T.N. Duong. (2006). The role of sucrose and different cytokinins in the in vitro floral morphogenesis of rose (hybrid tea) cv. “First Prize”. Plant Cell Tiss. Org. Cult. 87: 315-320.

Nickel LG. Plant growth regulators. Agricultural uses. Springer, New York. 1990, 4-5.

Nicole, L. W., John, F., & Michelle, L. J. (2010). Benzyladenine and Gibberellin prevent leaf chlorosis in compositae family. *Horticulture Science*, *45*(6), 925-93.

Oh, W., Kim, J., Kim, Y. H., Lee, I. J., & Kim, K. S. (2015). Shoot elongation and gibberellin contents in Cyclamen persicum are influenced by temperature and light intensity. *Horticulture, Environment, and Biotechnology*, *56*(6), 762-768.

Oh, W., & Kim, K. S. (2014). Light intensity and temperature regulate petiole elongation by controlling the content of and sensitivity to gibberellin in Cyclamen persicum. *Horticulture, Environment, and Biotechnology*, *55*(3), 175-182.

Ohkawa, K. (1978). Effects of gibberellin and benzyladenine on dormancy and flowering of lilium speciosum. Kanagawa Horticultural Experimental Station, Ninomiya, Nakagun, Kanagawa, Japan. pp.259-261.

Padhye, S., Runkle, E., Olrich, M., & Reinbold, L. (2008). Improving branching and postharvest quality. *Greenhouse Prod. News*, *8*(8).

Pop, T. I., Pamfil, D., & Bellini, C. (2011). Auxin control in the formation of adventitious roots. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *39*(1), 307-316.

Rademacher, W. (2015). Plant growth regulators: backgrounds and uses in plant production. *Journal of plant growth regulation*, *34*(4), 845-872.

Ramesh, K. M., Selvarajan, M., & Chezhiyan, N. (2001). Effect of certain growth substances and salicylic acid on growth and yield of China aster Cv. *Kamini*, *Orissa J. Hort*, *29*(2), 14-18.

Ranwala, A.P.; Miller, W.B. (2002). Effects of gibberellin treatments on flower and leaf quality of cut hybrid lilies. Acta Horticulturae 570: 205-210

Riaz, A., Z. Batool, A. Younis and L. Abid. (2002). Green areas: a source of healthy environment for people and value addition to property. Int. J. Agric. Biol. 4:478-481.

Richmond, A. E., & Lang, A. (1957). Effect of kinetin on protein content and survival of detached Xanthium leaves. *Science*, *125*(3249), 650-651.

Sakai, W. S., Courtney-Suttle, J., Clarke, J., Munekata, M., & Kaipo, R. (1998). Inducing dendrobium orchid inflorescence growth by injection of a solution of benzyladenine. *J. Hawaiian Pacific Agric*, *9*, 33-36.

ŠEBÁNEK J. Vegetative physiology tree propagation. Brno, Mendel University of Agriculture and Forestry in Brno, 2008, 60. 1st ed. ISBN 978-80-7375-238-5.

Sharma, R. (2014). *Study on the effect of Auxins on Rooting, Growth and Flowering of African Marigold (Tagetes erecta L.) propagated through stem cuttings* (Doctoral dissertation, Indira Gandhi Krishi Vishwavidyalaya Raipur).

Simpson, B.B. and M.C. Ogorzaly. (2001). Economic Botany, Plants in our World. McGraw-Hill, Boston, USA.

Singh, A. K., Sisodia, A., & Kumar, R. (2013). Effect of GA3 on growth and flowering attributes of gladiolus cultivars. *Annals of Agricultural Research*, *34*(4).

Singh, A. K., & Singh, R. (2005). Influence of growth regulating substances on rooting of cuttings of poinsettia cv. Flaming Sphere. *Progressive Horticulture*, *37*(1), 85.

Singh MK, Ram R, Kumar S. (2006). Effect of plant growth regulators on rooting of carnation (Dianthus caryophyllus) cuttings. J. Ornam. Hortic. 7(2):18-20.

Skalák, J., Černý, M., Jedelský, P., Dobrá, J., Ge, E., Novák, J., ... & Brzobohatý, B. (2016). Stimulation of ipt overexpression as a tool to elucidate the role of cytokinins in high temperature responses of Arabidopsis thaliana. *Journal of experimental botany*, *67*(9), 2861-2873.

Taiz, L. and E. Zeiger. (2002). Abscisic acid: A seed maturation and antistress signal, p. 539–558.

Tavares ST, Almeida AFE (2005). Development of calla lily plantlets submitted to pré-treatment with gibberellic acid and cultivated in different substrates. Revista Brasileira de Horticultura Ornamental. 1: 89-99.

Thimann, K. V. (1963). Plant growth substances; past, present and future. *Annual Review of Plant Physiology*, *14*(1), 1-19.

Toscano, S., Trivellini, A., Ferrante, A., & Romano, D. (2018). Physiological mechanisms for delaying the leaf yellowing of potted geranium plants. *Scientia Horticulturae*, *242*, 146-154.

Umrao, V.K., Singh, R.P. and Singh, A.R. (2006). Influence of ethrel and sand on growth and corm yield of gladiolus cv. Congo Song. Prog. Agric., 6 (2): 143- 145.

Urbanova, T., & Leubner‐Metzger, G. (2018). Gibberellins and seed germination. *Annual Plant Reviews online*, 253-284.

Vlahos, J.C. (1985). Effects of GA3 and BA on two cultivars of Achimenes longiflora under two levels of irradiance. Acta Hort. 167:225-235.

Wani, M. A., Wani, S. A., Ahmad, M. S., Lone, R. A., Gani, G., & FU, K. (2017). Integrated Nutrient Management (INM) approaches in flower crops. *Int. J. Curr. Microbiol. App. Sci*, *6*(3), 254-265.

Werner, T., Motyka, V., Laucou, V., Smets, R., Van Onckelen, H., & Schmülling, T. (2003). Cytokinin-deficient transgenic Arabidopsis plants show multiple developmental alterations indicating opposite functions of cytokinins in the regulation of shoot and root meristem activity. *The Plant Cell*, *15*(11), 2532-2550.

Wilkie, J. D., Sedgley, M., & Olesen, T. (2008). Regulation of floral initiation in horticultural trees. *Journal of experimental botany*, *59*(12), 3215-3228.

Yadav, K. S., Singh, A. K., & Sisodia, A. N. J. A. N. A. (2015). Effect of growth promoting chemicals on growth, flowering and seeds attributes in marigold. *Annals of Plant and Soil Research*, *17*(3), 253-256.

Yamazaki, H., Nishijima, T., & Koshioka, M. (1995). Effects of (+)-S-abscisic acid on the quality of stored cucumber and tomato seedlings. *HortScience*, *30*(1), 80-82.

Zalewska, M., Antkowiak, M., & Tymoszuk, A. (2012). Micropropagation of Ajania pacifica (Nakai) Bremer et Humphries with single-node method. *Nauka Przyroda Technologie*, *6*(1), 10.

Zhang, D. P. (Ed.). (2014). *Abscisic acid: metabolism, transport and signaling*. Springer Netherlands.

Zulfiqar, F., Younis, A., Abideen, Z., Francini, A., & Ferrante, A. (2019). Bioregulators Can Improve Biomass Production, Photosynthetic Efficiency, and Ornamental Quality of Gazania rigens L. *Agronomy*, *9*(11), 773.