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SL Pal
Department of Horticulture, RSM (PG) College Dhampur, Bijnor, Uttar Pradesh, India

Role of plant growth regulators in floriculture: An overview

SL Pal

Abstract
Plant growth regulators are being used by the commercial growers of ornamental plants as a part of cultural practice. Plant growth regulators have quicker impact on vegetative as well as flower yield of flowering crops. As it have various advantages like less time consuming to treat the plant and environment friendly. There are various factors contributing to the efficacy of plant growth regulators among them the method of application plays a key role in determining the effectiveness of plant growth regulators, as PGRs can be effective if properly absorbed by plants. Use of growth regulators in flowering crops must be specific their action and toxicologically and environmentally safe. The physiological activities of flowering crops regulate by the application of growth regulators and finally affect the growth and flower production in flowering crops. In the present overview, we discuss the types of plant growth regulators their effect and its applications in flowering crops.

Keywords: Plant growth regulators, PGR, flowering crops

Introduction
Floriculture is the segment of horticulture concerned with commercial production, marketing, and sale of bedding plants, cut flowers, potted flowering plants, foliage plants, flower arrangements, and non-commercial home gardening. Ornamental plants represent a great diversity of beautiful plants, including cut foliage, cut flowers, bedding plants, indoor plants, potted plants, bulbous flowering plants, outdoor plants, which may be annuals, biennials or perennials in their growth habit. There are different uses of ornamental plants, among them, cut flowers have more importance followed by, flowering potted plants, tree, nursery plants, and flower bulbs (Lawson, 1996) [17] but now the trend has been changed. The rapid rise is seen in the production of horticultural crops, including the ornamental plants (Janick, 2007) [13]. The ornamental plants (flowering and potted) having value of 32 billion euro were produced in the world during the year 2014 and Europe contributed 34.3% followed by China (15.9%) (AIPH, 2015) [2]. According to The International Association of Horticultural Producers (AIPH, 2015) [2], 702,383 ha area was under flower production in different countries of the world, of which the total area in Europe was 48,705 ha, 1,067 ha in North America, 523,829 ha in Asia, 4,026 ha in middle East, 7,604 ha in Africa, 21,067 ha in North America and and South America, it was the 97,152 ha. The total area under floriculture in India is 248.51 thousand hactare with production of 1685 thousand tonnes loose flowers and 472 thousand tonnes of cut flowers during 2014-15 (www.apeda.gov.in). Total export of floriculture products during the year 2015-16 was 22,518 MT with value of Rs. 479 crores (www.apeda.gov.in). To increasing the production and get more income by flower production in the country, There is as such an urgent need of scientific approach and wise use to promote the relevant management practices, improvement of flower germplasm, balanced nutrient management, modern production technology, quality planting material, precision farming etc., for conservation and commercialization of the floriculture industry and diversification from the traditional field crops due to higher returns per unit area. The overall strategy for increasing crop yields and sustaining them at high level must include integrated approach to the management of nutrients (Wani *et al*., 2017, Kumar and Chaudhary, 2018) [42, 16]. There are peak and lean productive seasons with consequent gluts and scarcity which affect the price trends greatly. Developments after the discovery of growth regulators and their application in agriculture and more especially in floriculture are significant. Regulations of plant growth and development using natural plant hormones for greater production have received the almost attention. Growth and flowering responses of ornamental plant to these chemical substances have been intensively studied with a view to have compact plants with greater number of flowers and also to hasten or delay flowering according to the needs of the grower. Plant growth regulators (PGRs) consist of organic molecules produced synthetically and used to

Correspondence
SL Pal
Department of Horticulture, RSM (PG) College Dhampur, Bijnor, Uttar Pradesh, India

alter the growth of plants or plant parts. Although, photosynthesis supplies the carbon and respiration supplies the energy for plant growth, a group of chemicals produced by plants known as plant growth regulators control the growth and development of plants. These chemicals act on plant processes at very low concentrations. They have ability to accelerate or retard the plant growth. PGRs sometimes confused with plant hormones, but there are certain differences among them as the term PGRs is used by agrochemical industry to indicate synthetic plant growth regulators, while plant hormones are a group of naturally occurring, organic substances which influence physiological processes at low concentrations (Davies, 2010) [5]. The growth hormone is the phytohormone and is essential to growth of organs as buds, stems, roots, fruits, and so on by cellular enlargement, both in length and in width, while growth regulator referred to organic compounds other than nutrients, small amounts of which are capable of modifying growth (Leopold, 1955) [18]. The PGRs can be bio-stimulant or bio-inhibitor and are active even at very low concentrations in plant cells and have ability to alter the growth and development. The plant growth regulators represents various categories and as American Society for Horticultural Science has been classified into six classes including gibberellins, auxins, cytokinins, ethylene generators, growth inhibitors and growth retardants. There are certain other groups which are considered as PGRs including polyamines, as they have an important role in plants and are also categorized as a new class of plant growth bio regulators due to their promotive effect on plant growth (Mahgoub *et al*., 2006, 2011) [19, 20] and vitamins which are also considered as growth bio-regulators as their low concentration may exert a great influence on factors that affect metabolic pathways, plant growth regulation and physiological processes including synthesis of enzymes and co-enzymes (Robinson, 1973 Hathout, 1995) [33, 12]. There are various products (synthetic growth regulators) commercial available for growth and development of ornamental plants.

Types and effect of plant growth regulators in flowering crops

1. AUXIN- Auxins are a group of phytohormones produced in the shoot and root apices and they migrate from the apex to the zone of elongation. Auxins promote the growth along the longitudinal axis of the plant. Auxins are widely distributed throughout the plant however, abundant in the growing tips such as coleoptile tip, buds, root tips and leaves. Indole Acetic Acid (IAA) is the only naturally occurring auxin in plants.

The synthetic auxins include

IBA: Indole Butyric Acid
NAA: Naphthalene Acetic acid
MENA: Methyl ester of Naphthalene acetic acid
MCPA: 2 Methyl 4 chloro phenoxy 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

Natural auxins may occur in the form of either free auxins- which freely move or diffuse out of the plant tissues readily or bound auxins- which are released from plant tissues only after hydrolysis, autolysis or enzymolysis.

Physiological effects of auxin

1. Cell division and elongation

The primary physiological effects of auxin are cell division and cell elongation in the shoots. It is important in the secondary growth of stem and differentiation of xylem and phloem tissues.

2. Apical dominance

In many flowering plants, if the terminal bud is intact and growing, the growth of lateral buds just below it remains suppressed. Removal of the apical bud results in the rapid growth of lateral buds. This phenomenon in which the apical bud dominates over the lateral buds and does not allow the lateral buds to grow is known as apical dominance.

Root initiation

Auxin play an important role in root initation in flowering plants. In contrast to stem, the higher concentration of auxin inhibits the elongation of roots but the number of lateral roots is considerably increased i.e., higher concentration of auxin induces more lateral branch roots. Application of IAA in lanolin paste (lanolin is a soft fat prepared from wool and is good solvent for auxin) to the cut end of a young stem results in an early and extensive rooting. This fact is of great practical importance and has been widely utilized to promote root formation in economically useful plants which are propagated by cuttings.

3. Respiration

Auxin stimulates respiration and observed that there is a correlation between inducing growth and respiration by auxin. It has been reported that auxin may increase the rate of respiration indirectly through increased supply of ADP by rapidly utilizing ATP in the expanding cells.

4. Callus formation

Besides cell elongation, auxin may also be active in cell division. In many tissue cultures, where the callus growth is quite normal, the continued growth of such callus takes place only after the addition of auxin.

5. Eradication of weeds

Plant growth regulators are also used for weed control. Some synthetic auxins especially 2, 4- D and 2, 4, 5-T are useful in eradication of weeds at higher concentrations.

6. Flowering and sex expression

It has been reported that auxins generally inhibit flowering in ornamental plants but in pine apple and lettuce it promotes uniform flowering.

Distribution of auxin in plants

In plants, auxin like (IAA) is synthesized in growing tips or meristematic regions from where; it is transported to other plant parts. Hence, the highest concentration of IAA is found in growing shoot tips, young leaves and developing auxiliary shoots. In monocot seedling, the highest concentration of auxin is found in coleoptile tip which decreases progressively towards its base.

In dicot seedlings, the highest concentration is found in growing regions of shoot, young leaves and developing auxiliary shoots. Within the plants, auxin may present in two forms. i.e., free auxins and bound auxins. Free auxins are those which are easily extracted by various organic solvents such as diethyl ether. Bound auxins on the other hand, need more drastic methods such as hydrolysis, autolysis, enzymolysis etc. for extraction of auxin. Bound auxins occur in plants as complexes with carbohydrates such as glucose, arabionse or sugar alcohols or proteins or amino acids such as aspartate, glutamate or with inositol.

Mechanism of Action
IAA increases the plasticity of cell walls so that the cells stretch easily in response to turgor pressure. It has been suggested that IAA acts upon DNA to influence the production of mRNA. The mRNA codes for specific enzymes responsible for expansion of cell walls. Recent evidences indicate that IAA increases oxidative phosphorylation in respiration and enhanced oxygen uptake. The growth stimulation might be due to increased energy supply and it is also demonstrated that auxin induces production of ethylene in plants.

Application of auxin in ornamental crops
Sharma *et al*. (1995) [35] reported the effect of foliar application of plant growth regulators on growth and flowering of chrysanthemum var. Move-in-Carvin. Plants were sprayed with Malleic hydrazide (MH) (250, 500, 750 and 1000 ppm), NAA (25, 50, 75 and 100 ppm) and control. Plant height was inversely proportional to MH concentration and directly proportional to that of NAA. MH and NAA had no effect on plant girth. Dorajeerao and Mokashi (2012) [6] noted that foliar spray of cycocel at 3000 ppm produced maximum number of flowers per plant, when compared to other concentrations. SA (salicylic acid) spray at 100 ppm resulted significant increase in flower and seed yield when compared to other concentrations. Paclobutrazol at 40 ppm recorded a higher number of flowers per plant compared to other higher concentrations of 60 and 80 ppm. Flower quality in terms of average flower weight, flower diameter and seed quality in terms of test weight were also at maximum by the application of GA_3 at 100 ppm. Hatamzadeh *et al*., (2012) [11] assessed the effect of salicylic acid (SA) on the quality and vase life of cut *Gladiolus cv*. “Wings Sensation” flowers over four developmental stages (bud stage; half bloom; full bloom; senescence). The flowers were treated in different concentrations of SA (50, 100, 150 and 200 mg/L). The results showed that the SA delayed flower senescence and leakage of ion in petals, as well as decreased fresh weight loss and lipid peroxidation. Roodbaraky *et al.*, (2012) [34] studied the effect of salicylic acid on vase life and postharvest quality of cut carnation (*Dianthus caryophyllus* L. ‘Liberty Abgr’). Application of 150 mg/l salicylic acid had the priority in 3 traits: 12.67 days vase life, 48.17 log10CFUml^{-1} bacterial clonies and 12.86% dry matter percent and the application of 50 mg/l salicylic acid had the maximum water uptake (1.59 ml l-1 F.W.) in carnation. Faraji and Basaki (2014) [7] observed the effect of Indole-3-acetic acid (IAA) and benzyladenine (BA) on growth, flowering and corm production of cut flower gladiolus cv. White Prosperity. Primarily bulbs were treated with four different concentrations of IAA (0,100,150, 200 mg/l) and benzyl adenine (0, 100, 150, 200 mg/l). The results indicated that IAA and BA increased germination rate of gladiolus. Also, onset stalk flower, diameter of floret and bulb wing affected by IAA and BA. The results showed that highest content of sugar were in petal and leaves which were treated with IAA 100 and 200 mg/l.

2. Gibberellins
Physiological effects of gibberellins
1. Seed germination
Plant growth regulators play an important role in seed/corm germination in flowering plants. Similarly, GA_3 induces the formation of hydrolytic enzymes which regulates the mobilization of reserves, ultimately resulting early sprouting of gladiolus corm (Groot and Karssen, 1987) [10]. GA3 also was very much effective for seed germination, growth promotion, flowering and senescence inhibition (Murti and Upreti, 1995) [22].

2. Dormancy of buds/corms
In temperature regions the buds formed in autumn remain dormant until next spring due to severe cold. This dormancy of buds can be broken by gibberellin treatments. In bulbous flowering crops, there is a dormant period after harvest, but the application of gibberellin sprouts the refer vigorously.

3. Root growth
Gibberellins have little or no effect on root growth. At higher concentration, some inhibition of root growth may occur. The initiation of roots is markedly inhibited by gibberellins in isolated cuttings**.**

4. Elongation of internodes
The most pronounced effect of gibberellins on the plant growth is the elongation of the internodes. Therefore in many plants such as dwarf pea, dwarf maize etc gibberellins overcome the genetic dwarfism.

5. Bolting and flowering
In many herbaceous plants, the early period of growth shows rosette habit with short stem and small leaves. Under short days, the rosette habit is retained while under long days bolting occurs i.e. the stem elongates rapidly and is converted into polar axis bearing flower primordia. This bolting can also be induced in such plants by the application of gibberellins even under non-inductive short days. In Hyoscyamus niger (a long day plant) gibberellin treatment causes bolting and flowering under non-inductive short days. While in long day plants the gibberellin treatment usually results in early flowering. In short day plants, its effects are quite variable. It may either have no effect or inhibit or may activate flowering**.**

6. Synthesis of the enzyme α – amylase
One important function of gibberellins is to cause the synthesis of the enzyme α **-** amylase in the aleurone layer of the endosperm of cereal grains during germination. This enzyme brings about hydrolysis of starch to form simple sugars which are then translocated to growing embryo to provide energy source.

Distribution of gibberellins in plant
Gibberellins are found in all parts of higher plants including shoots, roots, leaves, flower, petals, anthers and seeds. In general, reproductive parts contain much higher concentrations of gibberellins than the negative parts. Immature seeds are especially rich in gibberellins (10-100 mg per g fresh weight). In plants, gibberellins occur in two forms free gibberellins and bound gibberellins. Bound gibberellins usually occur as gibberellin – glycosides.

Applications of gibberellins in ornamental crops
Ramesh *et al,* (2001) [30] revealed that the application of gibberellic acid @ 150 ppm had, maximum plant height (75.10 cm) in china aster whereas highest number of branches per plant (13.15) noted with Malleic Hydrazide @1500 ppm. Maurya and Nagda (2002) [21] found that foliar application of

GA_3 at 100 ppm at 45 days after corm planting resulted highest plant height (104.5 cm), number of leaves (8.5 per plant), spike length (98.3 cm), number of florets (16.7 per spike), size of second florets (10.8 cm) and number of spikes per plant (1.73). While the highest floret opening longevity or survival was obtained with Cycocel at 1000 ppm in *Gladiolus grandiflorus cv.* Friendship. Rana *et al.,* (2005) [31] carried out study to assess the effect of different levels of GA_3, spacing and depth of planting on growth, flowering and corm production parameters in gladiolus cv. Candyman. The treatments consisted of four concentrations of GA3 (0, 100, 250 and 500 ppm) as foliar spray, three plant spacings (20 x 20, 30 x 20 and 40 x 20 cm) and two depths of corm planting (5 and 10 cm). Gibberellic acid @ 100 ppm, plant spacing of 30x 20 cm and planting depth of 10 cm resulted in maximum plant height, number of leaves/ plant, length of leaf and corm production. Ram *et al.* (2012a) [28] assessed the effect of salicylic acid on growth and flowering of gladiolus. The results showed that the foliar application of 100 ppm salicylic acid increased number of leaves, leaf length, leaf width, number of flowers, emergence of earlier spike and opening of flower. However, the plants treated sprayed with 50 ppm foliar spray of salicylic acid maximum plant height, rachis length and floret diameter. Ram *et al*. (2012b) [29] studied the effect of spacing (20x10, 20x20 and 20x30), dose of vermicompost (0, 1.0 and 2.0 ton/ha) and foliar application of salicylic acid (0, 50 and 100 ppm) on the growth and flowering of gladiolus. Significant improvement in growth and flowering characters was recorded with the corm planted at wider spacing (20x20) over those grown at closer spacing (20x10 and 20x20). Gradual increase in the dose of vermicompost for 0 to 2.0 tone/ha significantly improved plant growth and flowering quality. Higher concentration of salicylic acid (100 ppm) significantly notably produced good plant growth and flower yield but also induced early flowering. Kumar, (2015) [14] assessed the effect of pulsing solutions on postharvest life of gladiolus cv. Peater Pears cut spikes. Among all the pulsing treatments, treatment, T_4 (20% Sugar + 200ppm STS + 200 ppm GA_3) gave maximum vase life, floret size, minimum days to open basal floret, maximum floret longevity, floret opening percentage while treatment T_7 (20% sucrose + 300 ppm Al2SO4 + 200 ppm GA_3) attained maximum number of floret, floret weight and floret open at a time during the study. Raj *et al*. (2013) [27] studied the effect of preservative solutions on post-harvest quality of rose. The plants pulsed with 4% sucrose + 200 ppm salicylic acid attained maximum fresh weight and dry weight of flowers. Singh *et al.,* (2013) [36] studied the effect of GA_3 on growth and flowering attributes in gladiolus cultivars. The results revealed that maximum length of leaf and width of longest leaf were recorded with GA3 at 400 ppm on cvs. Sabnum and Gunjan. Maximum number of leaves per plant was registered with cv. Gunjan at 200 ppm GA_3. Among flowering parameters early spike emergence was noticed in cv. Sabnum when, GA_3 was sprayed at higher concentrations (300-400 ppm). GA_3 at 300 ppm exerted maximum length of spike, whereas maximum number of florets per spike was recorded with cv. Snow Princess when GA_3 was applied at 100-200 ppm. Uddin *et al.,* (2013) [41] conducted an experiment to study the effect of GA3 (0, 50, 100, 150 and 200 ppm) on growth and flowering of Gladiolus. GA3 150 ppm showed the highest plant height (131.2 cm) at harvest, number of florets/spike (14.1), length of flower stalk (74.2 cm), weight of single spike at harvest (62.2 g) and yield (327700 spike/ha). So, it is concluded that GA3 150 ppm application is the most effective for improving the growth and flowering of gladiolus for summer season cultivation of gladiolus. Tiwari *et al.,* (2018 a)[39] observed maximum plant height, plant spread, number of branches per plant, earliest flower bud initiation, days taken to opening of first flower, duration of flowering, length of flower stalk, diameter of flower and number of flowers per plant with the application of 100% R.D of NPK (100 kg N, 75 kg P and 75 kg K) + 25% R.D of Vermicompost (17.85 q/ha) + GA3 100 ppm and minimum values exhibited by control in marigold. Tiwari *et al.,* (2018 b)[40] assessed the effect of organic and inorganic fertilizers with foliar application of gibberellic acid on productivity, profitability and soil health of Marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda. The results revealed that maximum plant height, plant spread, number of branches per plant, earliest flower bud initiation, days taken to opening of first flower, duration of flowering, length of flower stalk, diameter of flower, number of flowers per plant, weight of flower, flower yield, net return and cost: benefit ratio were under the treatments 100% R.D of NPK (100 kg N, 75 kg P and 75 kg K) + 25 % R.D of vermi-compost (17.9 q/ha) + GA3 100 ppm followed by, 100% R.D of NPK (100 kg N, 75 kg P and 75 kg K) + 25% R.D of FYM (50 q/ha) + GA3 100 ppm. The highest population of bacteria, fungi, actinomycetes and organic carbon were found under 100% R.D of NPK (100 kg N, 75 kg P and 75 kg K) + 25% R.D of FYM (50 q/ha). Moreover, highest microbial organic carbon was under 100% R.D of NPK (100 kg N, 75 kg P and 75 kg K) + 25 % R.D of vermi-compost. The application of 100% R.D of NPK (100 kg N, 75 kg P and 75 kg K) + 25 % R.D of vermi-compost (17.85 q/ha) + GA3 100 ppm was found to be most effective treatment for productivity, and profitability of Marigold. However, treatment 100 % RDF and 25 % % RD of FYM was superior for soil health under sub-tropical climatic conditions of western Uttar Pradesh.

3. Cytokinins (Kinetin)

Kinetin was discovered by *Skoog et al., (*1965) [37] who reported its specific effect on cell division, it was called as cytokinins or kinetin. It is also known as phytokinins for cytokinins because of their plant origin. Chemically cytokinins are kinins and they are purine derivatives.

Cytokinins, besides their main effect on cell division, it also regulates growth and hence they are considered as natural plant growth hormones. Some of the very important and commonly known naturally occurring cytokinins are Coconut milk factor and Zeatin. It was also identified that cytokinin as a constituent of t-RNA.

Naturally occurring cytokinins

Cytokinins can be extracted from coconut milk (liquid endosperm of coconut), tomato juice, flowers and fruits of Pyrus malus; fruits of *Pyrus communis* (Pear), *Prunus cerasiferae* (plum) and *Lycopersicum esculentum* (bhendi); Cambial tissues of *Pinus radiata*, *Eucalyptus regnans* and *Nicotiana tabacum*; immature fruits of Zea mays, *Juglans sp*. and *Musa sp*; female gametophytes of Ginkgo biloba; fruitlets, embryo and endosperms of *Prunus persica*; seedling of *Pisum sativum*; root exudates of *Helianthus annuus* and tumour tissues of tobacco.

Physiological effects of cytokinins

1. Cell division

The most important biological effect of kinetin on plants is to induce cell division especially in tobacco pith callus, carrot root tissue, soybean cotyledon, pea callus etc.

2. Cell enlargement

Like auxins and gibberellins, the kinetin may also induce cell enlargement. Significant cell enlargement has been observed in the leaves of *Phaseolus vulgaris*, pumpkin cotyledons, tobacco pith culture, cortical cells of tobacco roots etc.

3. Concentration of apical dominance

External application of cytokinin promotes the growth of lateral buds and hence counter acts the effect of apical dominance

4. Dormancy of seeds

Seed dormancy is mechanisms by which seed scan inhibit their germination in order to wait for more favorable conditions (secondary dormancy) (Finkelstein *et al.*, 2008) [8]. However, primary dormancy is caused by the effect of absicic acid during seed development. Such seeds may never germinate (Bewley, 1997) [3].

Delay of senescence

The senescence of leaves usually accompanies with loss of chlorophyll and rapid breakdown of proteins. Senescence can be postponed to several days by kinetin treatment by improving RNA synthesis followed by protein synthesis. Richmand and Lang (1957) [32] while working on detached leaves of Xanthium found that kinetin was able to postpone the senescence for a number of days.

5. Flower induction

Cytokinins can be successfully employed to induce flowering in short day plants.

6. Morphogenesis

It has been well documented that high auxin and low kinetin produced only by roots whereas, high kinetin and low auxin could promote formation of shoot buds.

7. Accumulation and translocation of solutes

Plants accumulate solutes very actively with the help of cytokinin and also help in solute translocation in phloem.

8. Protein synthesis

Osborne (1962) [25] demonstrated the increased rate of protein synthesis due to translocation by kinetin treatment.

9. Other effects

Cytokinins provide resistance to high temperature, cold and diseases in some plants. They also help in flowering by substituting the photoperiodic requirements. In some cases, they stimulate synthesis of several enzymes involved in photosynthesis.

Application of cytokinins in ornamental crops

Nicola *et al*., (2010) [23] reported a combined application of both cytokinin and gibberellic acid @ 100ppm and 200ppm respectively prevented the leaf chlorosis and senescence in compositae family as compared to control plants. However, Yadav *et al.* (2015) [43] reported that application of kinetin @ 200 ppm produced maximum stem diameter, fresh weight of flower, early seed ripening and seed yield as compared to other levels in marigold.

4. Ethylene

Ethylene is the only natural plant growth hormone exists in gaseous form.

Important physiological effects

1. The main role of ethylene is it hastens the ripening.
2. It stimulates senescence and abscission of leaves
3. It is effective in inducing of flower
4. It causes inhibition of root growth
5. It stimulates the formation of adventitious roots
6. It stimulates fading of flowers
7. It stimulates epinasty of leaves.

Application of ethylene in ornamental crops

Gautam *et al.*, (2006) [9] observed the effect of plant growth regulators viz., GA3 (50, 100,150 and 200 ppm), NAA (50, 100, 150 and 200 ppm), Ethrel [ethephon] (>50, 1000, 1250 and 1500 ppm) and B-nine [daminozide] (1000, 1500, 2000 and 2500 ppm) on the growth of chrysanthemum cv. Nilima. The results revealed that GA^3 at all concentrations and NAA at 100 ppm increased plant height, internal length and basal diameter, while ethrel and B-nine at all concentrations retarded plant height, number of nodes and internodal length over control. However, number of branches and basal diameter were positively influenced by all treatments. Plant spread was influenced by all concentrations of GA^3 and NAA. Bharathi and Srivastava (2009) [4] used foliar application of growth regulators in three doses each GA3 (50, 100 and 150 ppm), Kinetin (50, 100 and 150 ppm), NAA (50, 100 and 150 ppm), Ethrel (100, 200 ad 300 ppm) and SADH (100, 200 and 300 ppm) on the flowering stage of two cultivars of tuberose viz., Shringar and Kalyani Double. Cultivar Shringar was superior in inducing early spike emergence, first floret opening and also produced maximum number of spikes/m2. However, cv. Kalyani Double showed maximum number of florets and spike length and flowering duration. Among various treatments, GA3 (150 ppm) was observed superior in inducing early spike emergence, opening of first floret, 50 per cent floret opening and maximum spike yield per square metre. The spike characters, such as length of rachis and spike, number of florets per spike, increased significantly with the application of GA3 (100 ppm). Maximum days to withering of first opened floret and flowering duration were observed with Kinetin (150 ppm). However, Ethrel (300 ppm) exhibited delayed flowering, minimum flowering duration and reduced length of spike characters.

5. Abscisic acid

Addicott *et al*., (1968) [1] isolated a substance strongly antagonistic to growth from young cotton fruits and named Abscissin II. Later on this name was changed to Abscisic acid. This substance also induces dormancy of buds therefore it also named as Dormin.

Abscisic acid is a naturally occurring growth inhibitor.

Physiological effects

The two main physiological effects are

1. Geotropism in roots

Geotropic curvature of root is mainly due to translocation of ABA in basipetal direction towards the root tip.

2. Stomatal closing

ABA is synthesized and stored in mesophyll chloroplast. In respond to water stress, the permeability of chloroplast membrane is lost which resulted is diffusion of ABA out of chloroplast into the cytoplasm of the mesophyll cells. From mesophyll cells it diffuses into guard cells where it causes closing of stomata.

3. Other effects

- Including bud dormancy and seed dormancy
- Includes tuberisation
- Induces senescence of leaves fruit ripening, abscission of leaves, flowers and fruits
- Increasing the resistance of temperate zone plants to frost injury.

Application of abscisic acid in ornamental crops

Kumar *et al.*, (2014) [15] performed a study to understand the role of abscisic acid (ABA) in ethylene insensitive floral senescence in gladiolus (*Gladiolus grandiflora* Hort.). It was observed that ABA accumulation increased in attached petals of gladiolus flowers as they senesced. Exogenous application of ABA in vase solution accelerated senescence process in the flowers due to change in various senescence indicators such as enhanced membrane leakage, reduced water uptake, reduced fresh weight and ultimately vase life. Attempts to increase vase life of flowers by application of putative ABA biosynthesis inhibitor fluridone in vase solution to counteract ABA effect were unsuccessful. In contrast, ABA action was mitigated by application of GA_3 in holding solution along with ABA which is basically an antagonist of ABA action. The present study provides valuable insights into the role of ABA as a hormonal trigger in ethylene insensitive senescence process and therefore would be helpful for dissecting the complex mechanism underlying ABA-regulated senescence process in gladiolus.

Growth retardants

There is number of synthesis compounds which prevent the gibberellins from exhibiting their usual responses in plants such as cell enlargement or stem elongation. So they are called as anti gibberellins or growth retardants. They are

- Cycocel (2- chloroethyl trimethyl ammonium chloride (CCC)
- Phosphon D – (2, 4 – dichlorobenzyl – tributyl phosphonium chloride)
- AMO – 1618
- Morphactins
- Maleic hydrazide

Application of growth retardants in ornamental crops

Qiu *et al.*, (1989) [26] observed the effects of paclobutrazol (PP333) and B-9 on stem elongation and flowering characteristics of chrysanthemum. Chrysanthemums planted in pots or in plots were sprayed with PP333 [paclobutrazol] at 250-2000 ppm or B9 [daminozide] at 1500-5000 ppm, 1-7 times. PP333 at 1000 ppm effectively inhibited growth, its effect varying with the number of sprays. Treated plants were shorter, with a green leaf colour, delayed flowering and a longer flowering period. B9 also inhibited growth, but its effect was significantly less than that of PP333. Yewale *et al.*, (1997) [44] observed the effect of growth retardant paclobutrazol on flowering of chrysanthemum. Thompson and Shefali plants were sprayed with paclobutrazol at 0, 25, 50, 75 and 100 ppm 1 month after planting the rooted cuttings. All paclobutrazol treatments delayed flowering. Flowering was increasingly delayed as the paclobutrazol concentration increased. Navale *et al.*, (2010) [24] studied the influence of plant growth regulators on growth, flowering and yield of chrysanthemum *(Dendrathema grandiflora Tzvelev)* cv. „IIHR-6". The results revealed that plants sprayed with MH 1250 ppm recorded the maximum reduction in plant height with maximum number of branches and plant spread. Tannirwar *et al.*, (2011) [38] observed the effects of gibberellic acid (50,100 and 200 ppm), maleic hydrazide (250, 500 and 1000 ppm), cycocel [chlormequat] (2000, 5000 and 8000 ppm) and 0.3% NPK (consisting of dihydrogen ammonium phosphate, urea, potassium phosphate and potassium nitrate at 1:2:1:1 (w/w) + 0.2% trace elements consisting of MgSO4, MnSO4, FeSO4, and borax at 4:3:2:1) on growth and flowering of chrysanthemum cv. Zipril. Gibberellic acid at 200 ppm resulted in the number of flowers per plant (148.73). Gibberellic acid at 50 ppm was superior to the other treatments in terms of early flower formation. Maleic hydrazide at 1000 ppm recorded the greatest flower diameter. The weight of flowers per plant was greatest for the nutrient spray.

Method of application of plant growth regulators on floricultural crops

1. Propagation

They are applied in the form of paste and solution. The concentration of the chemical varies with plant species and types of cutting and method of application.

IAA, IBA, and NAA are common plant growth regulators. In plant propagation two methods are used

a) Soak Method

The concentration of plant growth regulators varied from 10 to 100 ppm for 12 -24 hrs

b) Quick Dip Method

Quick dip method is one of the most important method for treating the seeds/vegetative parts of ornamental plants. The concentration of plant growth regulators for quick dip method varied from 1000 to 5000 ppm for 5 seconds. Among them, some growth regulators are used in layering, grafting and budding for getting high success.

2. Seed Germination

Plant growth regulators play an important role in seed germination of plants. It is well documented that gibberellic acid significantly accelerates seed germination in many plant species. Presoaking the seeds and bulbs/corms of flowering with gibberellic acid increase germination percentage.

3. Flowering duration

Plant growth regulators can be used for advancing and delaying the flowering. It has been noted that the foliar application of GA_3 causes early flowering in some ornamental plants.

4. Sex Expression

Application of plant growth regulators like auxins, gibberellins, ethylene and abscisic acid at the seat of ontogeny determines the sex ratio and sequence of flowering. Plant growth regulators (PGR) (GA_3, IBA, MH, ethephon and NAA) play an important role in plant morphology, growth and development. They are reported to influence the vegetative growth, flowering and sex expression in some ornamental plants

5. Sprouting of Bud

Ethrel, GA, thio urea, IBA and Cyotkininn, spray induces sprouting of buds.

8. Breaking of Dormancy

Plant growth regulators are also used for breaking the dormancy of seeds as well as corms/bulbs in various floricultural crops. GA_3, Ethrel, NAA are commonly growth regulators which are used for breaking the dormancy in seeds.

Conclusion

Plant growth regulators are valuable production tools that can enhance product quality and marketability while reducing labor for pinching and/or pruning and plant maintenance. They must be used with proper attention to other cultural practices, especially proper fertility and irrigation management. Plant growth regulators cannot correct poor production practices.

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