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HORTICULTURE

Plant Growth Regulators and their Implication in Ornamental Horticulture: An Overview

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ABSTRACT

Now a day, plant growth regulators have been used by the nurserymen and commercial growers of ornamental plants as a part of cultural practices. PGRs have quicker effect on ornamental plants including foliage and ornamental grassess to modify growth, foliage colour as well as flower yield. Application of growth regulators have various advantages on ornamental plants like less time consuming to treat the plant and its use are environment friendly. Various factors contributing to the efficacy of plant growth regulators among them the method of application plays a key role in determining the efficacy of plant growth regulators. PGRs and new class plant growth regulators can be very effective on flowering and foliage plants, if properly applied at appropriate concentrations and time. Implication of PGRs in flowering and foliage plants must be specific their action and ensure that it should be nontoxic and environmentally safe. It has been observed from various research reports that the physiological activities of flowering and foliage plants are regulated by the growth regulators and finally affects the growth of plants as well as flower production of various flowering plants. Plant growth regulators also play a significant role in propagation by means vegetative, seed treatment, *in vitro* propagation and *in vitro* rooting of ornamental and foliage plants. Besides these, PGRs are also involved in prolonging the life of flowers, vase life of cut flowers, plant growth promotion and regulation of flowering, breaking of dormancy in seeds, bulbs, corms and tubers of flowering plants, enhancing apical dominance, lateral branching, plant height control and delayed flowering. In the present overview, we discuss the types of plant growth regulators their applications and effect on flowering, foliage including ornamental grasses.

HIGHLIGHTS

- Plant growth regulators play a significant role in propagation by means vegetative, seed treatment, *in vitro* propagation and *in vitro* rooting of ornamental and foliage plants.
- PGRs are also involved in increase and decreased flower senescence, prolonging the life of flowers, plant growth promotion and regulation of flowering, post-harvest handling of cut flowers along with prolonging the self and vase life of flowers, breaking of dormancy in seeds including bulbs, corms and tubers of flowering plants, enhacing apical dominance and lateral branching, plant height control and deleyed flowering.

Keywords: Floriculture, foliage plants, plant growth regulators, yield, quality, post- harvest quality

PGRs have been used to change plant growth, flowering and yielding patterns in various horticulture crops including fruits (Bisht *et al.* 2018), vegetables (Dalai *et al.* 2015, 2016; Singh *et al.* 2015; Prajapati *et al.* 2015; Kaur *et al.* 2018; Sharma *et al.* 2020) and ornamental plants (Rana

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et al. 2005; Pal *et al.* 2015; Pal 2018). Plant growth regulators also play an important role in modifying the growth and flowering pattern in ornamental plants and its small quantity can promote, inhibits or quantitatively modifies growth and development in plants. Now a day, various number of growth regulators like GA_3, NAA, MH, Etheral, IAA, NAA, Brasinoides, Polyamines, Alar etc. are being tried for promote growth, flower yield and controlling growth with a view to have compact plants and hasten or delay the flowering period of ornamental plants. An optimum concentration of PGRs is more important for plants and higher concentrations of some PGRs can cause toxicity to the plant (Ranwala *et al.* 2002). There are various methods for applying PGRs on plants viz: pre plant soaking, drenching, foliar application on plants, seed priming, pasting, capillary string, injactions etc. Among the various methods, foliar applications of growth regulators have been prooved to be more effective if applied on plants at the right stage. More recently, the turf and sports industry has also been started work on application of PGRs to enhance turfgrass quality, greenery and its ability to tolerate environmental stress (Glab *et al*. 2020). Growth regulators are also being used for controlling growth of perennial ground covers and shrubs in the landscape (Gad *et al*. 2016; Wei *et al.* 2017; Glab *et al*. 2020). Among the growth regulators, application of gibberellic acid have been proved to be very effective in manipulating growth and flowering of various flowering crops (Kumar *et al.* 2011; Kumar *et al.* 2014a). Naphthalene Acetic Acid is involved in cell elongation and rapid cell stimulation leading to bigger plants and ultimately enhanced yields in flowering plants Palei *et al*. (2016). Indole Butyric Acid (IBA), Naphthalene Acetic Acid (NAA), Indole Acetic Acid (IAA) in single and in combined form have been been proved very effective in root initiation in cuttings of ornamental and foliage plants (Parminader and Kushal 2003; Kumar *et al.* 2014b; Gowda *et al.* 2017). In ornamental plants, Maleic hydrazide (MH) have been found to retard plant height by reducing internodal length and also simultaneously it reduces the formation of lateral shoots thereby plant produces more number of flower bearing shoot in African marigold (Kumar *et al.* 2014a). Alar may act as growth retardants and thereby inhibited biochemical processes resulting in retard plant height, number of nodes and internodal length, increase branching and delayed flowering in China aster (Kumar *et al.* 2015). Instead of these growth regulators, now a days brassinosteroids (BS), polyamines, jasmonic acid which are a new and unique class of plant growth regulators have also been used in various ornamental and foliage plants (Mahgoub *et al*. 2006, 2011; Nahed *et al*. 2009; Mahros *et al*. 2011; Padmalatha *et al.* 2015; Badawy *et al.* 2017; Sewedan *et al.* 2018). Therefore, in the present review, we have discussed the role of plant growth regulators and their effect on ornamental horticultural plants from available literature worldwide.

Types of Plant Growth Regulators: Plant growth hormones or regulators are of the following types:

1. Plant Growth Promoters
2. Plant Growth Inhibitors

Plant Growth Promoters: Plant growth promoters are intended to accelerate the rate of growth and flowering of plants. The plant growth regulators or hormones which promote plant growth are called growth promoter e.g. Auxins, Gibberellins and Cytokinins.

Auxins: The term Auxin is derived from the Greek words meaning to grow. Among the growth hormones, auxins are one of the most important plant hormones which were first discovered by the biologist Charles Darwin. The main naturally occurring auxin is indole-3 acetic acid – IAA and other related compounds. Among the auxins, Indole butyric acid (IBA) and NAA were found to increase root development in the propagation of stem cuttings and in vitro rooting while 2,4-dichlorophenoxyacetic acid (2,4-D) stimulates excessive, uncontrolled growth in broad leaf plants for which it is used as a herbicide.

Gibberellins: The first gibberellin to be discovered was gibberellic acid. GA in agriculture came in existed when this compound was rediscovered by US and British scientists in the 1950s. Now a days, there are more than 100 types of gibberellins and are mainly gathered from a variety of organisms from fungi to higher plants, although only two commercial products are available GAs and a mixture of GA_4 and GA_7. Gibberellins are delayed senescence in flowers, breaking of dormancy in seed/bulbs/corms of ornamental plants, use

in vitro protocol media and also improve growth and flowering in ornamental plants.

Cytokinins: Cytokinins are involved in the occurence of new leaves, lateral shoot growth, chloroplasts in leaves etc. They help in overcoming apical dominance and delay ageing of leaves, breaking of bud and seed dormancy including bulbs/corms/tubers, promote nutrient mobilization, uses in vitro protocol in media, promotes growth and lateral bud, increases longevity as well as vase life of flowers.

Plant Growth Inhibitors: Plant growth inhibitors are synthetic organic compounds which retarded cell division of plants by inhibiting biosynthesis of plant hormones without evocating substantial growth distortions e.g. onium compounds, pyrimidines, trizoles, tetcyclacis, morphactins, maleic hydrazide etc.

Abscisic acid: It is a growth inhibitor which was discovered in the 1960s. Earlier, it was initially called dormant but later, another compound abscisin-II was discovered and also known as abscisic acid. This growth inhibitor is synthesized within the stem, leaves, fruits, and seeds of the plant. Mostly, abscisic acid serves as an antagonist to gbberellic acid. Abscisic acid is also involved in stimulate and closing of stomata in the epidermis, maturation and development of seeds, induces seed-dormancy etc. It is also known as the stress hormone as it helps by increasing the plant-tolerance to various types of stress. It also inhibits mRNA and synthesis of protein.

Ethylene: Ethylene is a hydrocarbon gas and induces senescence in many flowers. Some important effects of ethylene are: Sleepiness of petals in carnation, Epinasty in Poinsettia, Abscission of petals or whole flowers, Inhibition or promotion of bud opening in roses (Gupta and Duvey 2018). Ethylene also involved in induction of femaleness in dioecious flowers and stimulates flower opening, facilitates senescence and abscission of both flowers and leaves etc. It is an unsaturated hydrocarbon having double covalent bonds between and adjacent to carbon atoms.

Application of growth regulators in ornamental horticulture: The term growth regulator is applied to organic compounds other than nutrients which minute quantities can inhibit, stimulate or alter growth and flowering pattern of ornamental plants. These broadly grouped in to two catogeries (i) Growth promoters which stimulates or alters the growth favourably and (ii) Growth retardants those inhibit or alter the growth negatively. Ornamental crops find extensive use of growth regulators for modifying their developmental processes. Within the broad group of plant hormones some act as growth promoters, others act as growth retardants.

The major areas where growth regulators are used in ornamental horticulture: Plant growth regulators in very minute quantities can induce above mentioned responses dramatically. The response to PGR's however varies with the cultivar, age of the plant, light, temperature, availability of mineral nutrients, vigour of the plant and its endogenous hormonal content. In ornamental and foliage plants, growth regulators are used in plant propagation, post harvest handling, increasing flower production, inhibit plant growth, foliage colour and visual quality of ornamental grasses etc. The application of plant growth regulators and their effective use on some ornamental horticultural plants for specific purposes are presented in (Table 1).

The application of plant growth regulators have been briefly discussed with the following heads—

1. Plant propagation: There are three methods of propagation employed in ornamental and foliage plants viz., asexual (vegetative methods); sexual (through seed) and micro-propagation (through tissue culture). However, majority of ornamental plants are propagated by vegetative methods such as stem, suckers, leaf cuttings, bulbs, corms and tubers etc.

(A) Vegetative propagation: Various ornamental crops like rose, carnation, chrysanthemum, gerbera, bougainvillea, jasminum etc. are propagated by vegetative methods. Plant growth regulators such as Auxins (IBA, NAA and IAA) are extensively used for rooting in cuttings. The most commonly and widely used auxin for promoting rooting is IBA (Indole Butyric acid) followed by, NAA and IAA. The mixtures of two or more auxins are also used and found more effective (synergistic effect) for rooting in ornamental and foliage plants. There are three methods of auxins application for inducing rooting:

1. Prolonged soak treatment for long duration i.e. 24 hours and more at low concentrations.

Table 1: Application of Growth regulators in some important ornamental plants

Sl. No.	Name of the plant	Purpose of study	Growth regulators	Methods of application	References
1	Grindelia	Rooting in cuttings	IBA	Dipping	Wassner and Ravetta (2000)
2	Dieffenbachia	Indirect shoot organogenesis	TDZ and 2,4D	Media solution	Shen *et al*. (2008)
3	Rose	*In vitro* shoot regeneration	NAA, BAP for Shoot generation and IAA and NAA for rooting	Media solution	Asadi *et al*. (2009)
4	Chrysanthemum	Flowering and chlorophyll content	Daminozide (Alar-85)	Foliar spray	Kazaz *et al*. (2010)
5	Hibiscus	Growth and flowering	Paclobutrazol, Uniconazole and Flurprimidol	Drenching	Ahmad Nazarudin (2012)
6	Rose	Flower and vase life of flowers	Spermidine (Spd)	Hydroponic culture media	Farahi *et al*. (2012)
7	Tuberose	Flower and bulb yield	Gibberellic acid (GA_3)	Dipping	Rani and Singh (2013)
8	*Tabernaemontana coronaria*	Growth, flowering and histological features	Paclobutrazol and Cycocel	Foliar spray	Youssef and Abd El-Aal (2013)
9	Marigold	Flower and yield	GA3, Ethrel and Maleic hydrazide	Foliar spray	Kumar *et al*. (2014a)
10	Carnation	Rooting efficiency	IBA, IAA and NAA	Dipping	Kumar *et al*. (2014b)
11	Annual Chrysanthemum	Flower and seed yield	GA_3	Foliar spray	Sainath Uppar *et al*. (2014)
12	Potted sunflower, Zinnia, Marigold, Petunia	Post harvest performance	Paclobutrazol	Drenching	Ahmad (2015)
13	China aster	Growth, flowering and seed yield	GA_3, Salicylic acid, Maleic hydrazide, Alar and Paclobutrazol	Foliar spray	Kumar *et al*. (2015)
14	Hippestrum	Flower and bulb production	IAA, Etheral and GA_3	Foliar spray	Jamil *et al*. (2015)
15	Gladiolus	Corm production and vase life	GA_3 and Brassinosteroid	Foliar spray	Padmalatha *et al*. (2015)
16	Gladiolus	Growth and flowering	GA_3 and CCC	Foliar spray	Sable *et al.* (2015)
17	Rose	Post harvest quality of flowers	Polyamines viz. spermine, spermidine and putrescine	Holding solution	Tatte *et al.* (2015)
18	Rose	Growth and flowering	Spermine and Spermidine	Foliar spray	Tatte *et al*. (2016)
19	Zinnia	Growth and flowering	Brassinosteroides	Foliar spray	Badawy *et al*. (2017)
20	Dahlia	Growth and flowering	Ethephon, Alar and Maleic hydrazide	Foliar spray	Malik *et al*. (2017)
21	Rose	Growth and flowering and vase life	Putrescine (Put), Spermidine (Spd)	Foliar application	Farahi and Jahroomi, (2018)
22.	Gladiolus	Morphological, biochemical and post harvest flowering	24-Epibrassinolide (EBR)	Priming of corms	Mollaei *et al*. (2018)
23.	Chrysanthemum	Growth and flowering	Cycocel and B-nine	Foliar spray	Qureshi *et al.* (2018)
24	Gladiolus	Growth, flowering and corm yield	Methyl- jasmonate and Salicylic acid	Foliar spray	Sewedan *et al.* (2018)
25	Anthurium	Post harvest quality of flowers	Gibberellic acid (GA_3) and Spermine (SPM),	Foliar spray and pulsing	Simões *et al.* (2018)

26	China aster	Flower yield and vase life	GA_3, NAA, CCC	Foliar spray	Sindhuja *et al*. (2018)
27	Chrysanthemum	Growth and flower yield	GA_3	Foliar spray	Ashutosh *et al*. (2019)
28	Rose	Growth , Development and antioxidant enzymes activities	Polyamine (Putrescine, Spermidine, and Spermine)	Foliar spray	Yousefi *et al*. (2019)
29	Turfgrass	Visual quality	Trinexapac Ethyl, Paclobutrazol, Flurprimidol, Mefluidide, Ethephon and Gibberellic Acid	—	Głąb *et al*. (2020)
30	Azalea	Rooting in cuttings	IBA, NAA, SA single and in combinations	Soaking	Hou *et al.* (2020)
31	Bahiagrass	Visual quality and biochemical analysis	Paclobutrazol	Foliar application	Lima Bruno Horschut de *et al.* (2020)
32	Carpet grass Plus®	Visual quality	Paclobutrazol and Phenoxaprope-pethyl	—	Melero *et al.* (2020)
33	Gerbera	Vase life, qualitative features and enzyme activity	Polyamines like spermine (SPER), γ-aminobutyric acid (GABA) and β-aminobutyric acid (BABA)	Vase solution and spray	Mohammadi *et al.* (2020)
34	Rhododendron	In vitro shoot proliferation	Thidiazuron (TDZ)	Media solution	Novikova *et al*. (2020)
35	Bougainvillea	Rooting in cuttings	IBA	Dipping	Pirdastan *et al*. (2020)
36	Iraca palm	In vitro shoot multiplication and rooting	BAP and NAA	Media solution	Sanchez *et al.* (2020)
37	Gladiolus	Growth and flowering	Ancymidol	Dipping	Aljaser and Anderson (2021)

2. Quick dip method-dipping where the basal portion of the cuttings are dipped in higher concentrations for 5 seconds to 2 minutes depending upon the nature of the cuttings, whether they are soft, semi hard or hard wood.
3. Dipping the wet basal portion of the cuttings in tale mixed with auxin.

Auxins play an important role for induction of primary root (PR), lateral root (LR) and root hair (RH) development (Osmont *et al.* 2007; Overvoorde *et al.* 2010; Benfey *et al.* 2010; Saini *et al.* 2013). However, the success of rooting depends on some external and internal factors like season, photoperiod, light intensity, temperature, aeration, humidity, nutrient status of cuttings and endogenous auxins level in the cuttings. PGRs have been used as plant growth substances for enhancing the rooting of cuttings. The most commonly rooting media is IBA, which having weak auxin activity, but is relatively stable and insensitive to the auxin-degrading enzyme systems and not readily translocated. Other rooting media such as NAA and 2,4-D also used to promote root development, but they are more easily translocated to other parts of the stem cutting where they may have toxic effects. IBA have been proved very effective for promotion of rooting percentage and other rooting parameters in carnation cuttings (Gowda *et al.* 2017; Kumar *et al.* 2014b; Ghofrani 2013) as well as initiated earlier rooting in cuttings (Singh *et al.* 2006; Bharathy *et al.* 2003). Application of different auxins and their level have been proved very effective in marigold for increasing rooting percentage, root length, number of roots and dry weight of roots (Bhatt *et al.* 2012; Sharma 2014; Majumder *et al.* 2014). Sharma *et al.* (2002) identified best treatment in acalypha when cuttings treated with 2000 ppm IBA, followed by cuttings treated with 2000 ppm IAA. Grewal *et al.* (2005) observed

that *Dendranthema grandiflora* cv. Snowball cuttings treated with IBA 400 ppm resulted in maximum rooting percentage and number of roots. Bharmal *et al.* (2005) noted that chrysanthemum cv. Sonali Tara treated with IBA 2000 ppm as a quick dip method along with 2 sprays of 10 ppm IBA after 30 and 60 days of planting of cuttings was significantly superior treatment over the other treatments viz; (1000, 2000 and 3000 ppm). Swetha (2005) reported that the IBA at 2000 ppm was found better induction of rooting as compared to control in Indian lavender (*Bursera delpechiana*). Ullah *et al.* (2013) obtained maximum number of roots in marigold with 400 ppm of IBA whereas; maximum root length noted with 100 ppm of IBA in marigold. IBA 2,000 mg L^{-1} enhanced root growth and development in Azelea and Paeonia respectively (Xian *et al.* 2009; Hou *et al.* 2020*)*. However, Chaudhari *et al*. (2018) treated the cuttings of poinsettia with IBA, 4000 ppm was found most effective. *Hibiscus rosa-sinensis* L. cuttings treated with NAA @ 200 ppm was found most effective in rooting and growth parameters as compared to control Nanda and Mishra. (2010). IBA @ 4000 ppm proved superior with respect to rooting percentage (%), survival percentage and took minimum number of days for sprouting in different cultivars of bougainbillea (Parmar *et al.* 2010; Sayedi *et al.* (2014). Dipping of cuttings in 1000 ppm IBA resulted with the highest number of root and shoots per cutting in bougainvillea (Gupta *et. al*., 2002, Mehraj *et al.* (2013). However, Panwar *et al.* (2001) and Sahariya *et al*. (2013) observed maximum number of roots, rooting percentage and root length in different cultivars of bougainvillea with 2000 ppm IBA. Singh et al. (2011) observed maximum length of sprout/cutting and number of roots/cutting in *Bougainvillea glabra* with 3000 mg.L^{-1} IBA in the month of February but maximum length of root/ cutting was observed with 5000 mg.L concentration of IBA. Pirdastan *et al.* (2020) noted that application of 400 mg/l IBA for 24 hrs dipping led to improve rooting parameters in bougainvillea. However, the use of 1000 mg/L IBA for 20 s as quick dipping also had satisfactory results, which can be introduced as a suitable treatment due to the reduction of application time and labor costs.

Plant growth regulators showed variable results when applied in single as well as in combination in media. Tripathi *et al*. (2003) examined the efficiency of two growth regulators for rooting in poinsettia and recorded highest number of roots per cutting with 1000 ppm NAA. The longest root was observed in 200 ppm IAA, whereas, the highest root fresh weight was observed with 100 ppm IAA. Parminder and Kushal (2003) noted maximum rooting parameters in bougainvillea cv. Cherry Blossom when cuttings were treated in a combination of NAA at 1500 ppm + IBA 1000 ppm. Vinaykumar *et al.* (2008) found highest percentage of rooting in combination of IBA + NAA 2000 ppm in stem cuttings of *Thunbergia grandiflora.* Rahbin *et al.* (2012) reported that stem cuttings of Night Queen (*Cestrum nocturnum*) treated with IBA 4000 ppm showed maximum rooting percentage, number of roots, root length, fresh weight and dry weight of root. Singh *et al.* (2013) observed highest number of roots per cutting with NAA 300 ppm while rooting percentage. length of roots per cutting, fresh weight and dry weight of roots were higher in IBA 100 ppm and the maximum length of sprout per cutting was observed under IBA 300 ppm in stem cuttings of Night Queen (*Cestrum nocturnum* L.). A various numbers of reports demonstrated that rose cuttings treated with auxins showed improvement in rooting parameters (Nasri *et al.* 2015; Akhtar *et al.* 2015; Yeshiwas *et al.* 2015 and Abbas *et al.* 2015). However, combination of two growth regulators have been reported by Haixia *et al.* (2013) where they found highest survival percentage of rose cuttings with a combination of NAA 250 ppm + IBA 250 ppm followed by IBA 250 ppm. Rahdari *et al.* (2014) showed highest root fresh weight, root dry weight, root length with a combination of NAA 2000 ppm + IBA 1000 ppm in stem cuttings of *Cordyline terminalis.* Wazir (2014) examined the efficiency of growth regulators in different type of cuttings. Hardwood cuttings and semi hardwood cutting treated with 1000 ppm IBA showed best performance in of *Camellia japonica*. Singh and Negi (2014) treated the 50 cm long cuttings of *Ticoma stans* L with 1500 ppm concentration of IBA and noted best results in rooting with growth parameters in field. Singh *et al.* (2014) observed highest number of roots per cutting, length of roots per cutting, diameter of root per cutting, percentage of rooted cutting, number of sprouts per cuttings with 1400 ppm IBA concentration in Golden Duranta.

(B). Seed propagation: All seasonal flowers like marigold, antirrhinum, pansy, petunia, phlox. verbena, sweet alyssum, candytuft, sweet sultan, coreopsis, gaillardia, larkspur, lupin, etc. are propagated by sexual method (by seed). Seed treatment with lower doses of gibberellic acid improves germination percentage, seedling vigour, final population etc. in many seed propagated seasonal flowers. Pill and Gunter (2001) failed to decrease shoot height in marigold when seed grown after soaked in 1000 ppm paclobutrazol (PB) as compared to non-treated seeds. However, 1000 ppm paclobutrazol (PB) treatment during priming of marigold seeds resulted in shoot height suppression (13%) as the growth medium drench, and similar shoot with dry weight reduction (21%) as the shoot spray. Drewes and Van Staden (1990) observed slight reduction in germination with continuous exposure of *Tagetes minuta* seeds to 10^{-6} M PB, and almost complete inhibition noted with 10^{-4} M PB. Singh *et al.* (2020a) treated seeds of marigold with 200 ppm GA_3 and observed significant and positive effect on germination and seedling parameters of potted marigold.

(C) Micro-propagation

(I) *In vitro* shoot elongation and multiplication: A wide range of PGRs viz; BA, 2,4-D, TDZ, zeatin (ZT), kinetin (Kin), NAA, indole-3-butyric acid (IBA), indole-3-acetic acid (IAA) sodium nitropruside, brasinoides etc. have been used in media for *in vitro* propagation of flowering and foliage plants. Cytokinins and auxins as separate and in combinations are widely used as supplement in media for induction of shoots and roots for *in vitro* culture of plants. Several reports have suggested that cytokinin is more effective for shoot organogenesis in various ornamental plants Babu and Chawla, 2000; Hussain *et al.* 2001; Krishnamurthy *et al.* 2001; Aftab *et al.* 2008; Jyothi *et al*. 2008; Sangavai and Chellapandi 2008; Asadi *et al*. 2009; Memon *et al*. 2010; Aslam *et al.* 2012; Tripathi *et al*. 2017; Sánchez *et al* 2020) and also encourages bud/shoot regeneration (Sinha and Roy 2002; Torabi-Giglou and Hajieghrari 2008 and Pragya *et al.* 2012). Among the cytokinins, beneficial effect of Benzyl aminopurine (BAP) or Benzyladenine (BA) over other cytokinins have been reported (Dantu and Bhojwani 1987; De Bruyn and Ferreira 1992; Jyothi *et al.* 2008; Asadi *et al.* 2009; Memon *et al.* 2010; 2012, 2013). Higher dose response of BAP is attributed to genotypic differences (Hussain *et al.* 2001). Gosal and Greval (1991) reported to response with higher concentration of BA for rapid shoot bud proliferation from nodal buds. BAP (5.0 mg/l) increased shoot bud proliferation alongwith increasing multiplication rate with 5 to 6 folds in each sub cultured after 4 to 5 weeks. Sánchez *et al.* (2020) obtained highest multiplication rate (17±3 shoots per explant) in *Iraca palm* with 2.0 mg/l BAP Similarily, concnetration of BAP (4 mg/l) was found for efficient shoot regeneration in gladiolus using different explants (Memon *et al.* (2010, 2012 and 2014).

In tuberose, Jyothi *et al.* (2008) regenerated of micro plantlets from two cultivars of tuberose with 4 mg/l BAP. Some authors have been recommended lower concentration of BAP in media for *in vitro* protocol. In anthurium, Huang *et al.* (2001) induced callus in *Anthurium warocqueanum* when BA concentration increased from 0.5 to 2.0 mg/l in media. Yuan *et al.* (2004) observed that BA concentration increased from 0.2 to 1.0 mg/l for callus induction in *Anthurium andraeanum*. Yang *et al.* (2008) optimized BA concentration 0.5 mg/l in media for callus induction of three *Anthurium andraeanum* varieties. Zhang *et al.* (2001) and Liu *et al.* (2009) also reported that callus differentiation and shoot formation of *Anthurium andraeanum* and both can be achieved at lower BA concentration (0.5 or 0.8 mg/l). Wu (2010) optimized BA concentration 2.0 mg/l for improved proliferation of *Anthurium andraeanum*. Mateen (2019) observed that Kinetin enhanced the shoot formation rate in gladiolus with decreasing time period.

Combinations of two and three growth regulators in media for *in vitro* propagation of ornamental plants have been reported by various workers (Krishnamurthy *et al.* (2001) Mishra *et al.* (2005), Jiang *et al*. 2006; Emek and Erdag 2007). Pan *et al.* (2000) and Cui *et al.* (2007) concluded that single PGRs like BA, Kin and 2,4-D are not capable for indirect organogenesis and combination of auxin and cytokinin(s) are necessary for callus induction. Higher concentration of BAP with lower concentration IAA have been reported by Posada *et al.* (1999) who had regenerated gerbera microplants with 10 mg/l BA and 0.1 mg/l IAA. Krishnamurthy

et al., (2001) got maximum shoot proliferation on media containing 2.0 mg/l BAP and 0.1 mg/l IAA in 'Shringar' and 'Suvasini' varieties of *Polianthes tuberosa*. Mishra *et al.* (2005) employed 4.0 mg/l BAP and 0.2 mg/l IBA and recorded maximum number of shoots while higher concentration of BAP more than 4.0 mg/l inhibited the number and length of shoots in tuberose. Samanta *et al*. (2015) used various combinations of IAA and BA for multiple shoot induction and best response of multiple shoot production noted on media containing 0.5 mg/l IAA and 3 mg/l BAP. Devi *et al*. (2019) induced high quality callus with 2.0 mg/l 2,4-D (2,4-Dichlorophenoxyacetic acid) while BAP at 2.0 mg/l exhibited higher shoot proliferating efficiency, i.e., shoots per explant in gladiolus cv. Sylvia. Maurya *et al*. (2019) induced high quality callus in carnation on media containing 0.25 mg/l BAP and 3.5 mg/l 2,4D. Higher IAA and lower concentrations of BA have also been reported by Lo *et al.* (1997) where they regenerated shoots from leaf discs of *Saintpaulia ionantha* on media containing 2.0 mg/l IAA and 0.08 mg/l BA. Carelli and Echeverrigaray, (2002) developed a protocol for *in vitro* propagation of hybrid roses and observed that media supplemented with 3.0 mg/l BA and 0.5 mg/l NAA showed maximum shoot proliferation. Addition of silver nitrate along with BA and IAA promoted the growth of the axillary shoots in rose as reported by (Chakrabarty *et al*. 2000). However, Copetta *et al.* (2020) obtained direct microplantlets in tuberose with on media fortified with 1.5 mg/l BA, 0.5 mg/l IAA. Higher concentration of NAA in single as well as in combination with other growth regulators has also reported by various workers. Bera *et al.* (2015) obtained swell like structure when explants were cultured on media supplemented with 2.0 mg/l NAA. Kabir *et al.* (2014) induced high quality callus with 7.5 mg/l NAA while shoots were developed on medium containing 0.5mg/l BAP 0.5mg/l kinetin. Emek and Erdag (2007) got more shoots per explants (4.71) with using the combination at low level of BA (0.2 mg/l) and high level of NAA (2 mg/l) in *Gladiolus anatolicus.* However, maximum callus induced by 8.5 mg/l NAA. Tyagi and Kothari, (2004) observed best shoot regeneration in gerbera with 4 mg/l of kinetin (Kin) combined with 0.5 mg/l IAA. Kumar *et al.* (2019) compared the efficiency in two media for callus induction in gerbera. Callus induced in minimum time with 2.00 mg/l IBA + 1.00 mg/l BAP with CHU media and SH media containing 2.00 mg/l IBA + 1.00 mg/l BAP showed minimum days for callus induction. Jiang *et al*. (2006) reported a combination of 0.1–0.2 mg/l 2,4-D and 0.5 mg/l BA for callus induction *Anthurium andraeanum* cv.'Pink Champion. 2.0 mg/l BAP showed maximum percentage of shoot formation in orchid while combination of BAP 2.0 mg/l and NAA1.5 mg/l had been registered for maximum percentage of formation of shoots while 4.0 mg/l BAP and 2.5 mg/l NAA exhibited least shoot formation (Kalimuthu *et al.* 2007).

Thidiazuron (TDZ), chemically known as 1-phenyl-3-(1, 2, 3-thiadiazol-5-yl) urea was first described as a cytokinin in 1982. It has been proved from various reports that TDZ has cytokinin-like activity and induces *in vitro* shoot organogenesis in a number of ornamental plants (Kumar *et al*. 2001; Rabori and Ghazvini 2009; Boldaji *et al.* (2021). In gerbera, Rabori and Ghazvini (2009) obtained highest number of shoots with 1 mg/l TDZ. Kumar *et al.* (2001) used 1.0–2.5 µM TDZ in media for higher shoot multiplication in *Rosa damascena*. Boldaji *et al.* (2021) reported that the rate of direct somatic embryogenesis (DSE) was highly dependent on the concentrations of TDZ and 3 mg/l TDZ resulted in induce DSE without somaclonal variation in *Phalaenopsis Orchid*. TDZ in combination with other growth regulators have been reported by Nazari *et al.* (2016) where they noted that media supplemented with 0.1 mg/l IAA, 1.0 mg/l TDZ and 4.0 mg/l BA showed maximum shoot regeneration in gerbera. Maurya *et al.* (2021) obtained maximum length of the micro-shoots with a combination of BAP 2.5 mg/l, TDZ 1.0 mg /l and $AgNO_3$ 1.5 mg /l in carnation.

(ii) *In vitro* rooting: *In vitro* rooting of ornamental and foliage plants by using different concentrations of growth regulators or completely elimination of growth regulators have been reported by various workers (Rajasekaran *et al*. 2000; Krishnamurthy *et al*. 2001; Mishra *et al*. 2006; Rezende *et al.* 2008; Kadam *et al*. 2009,). Increasing levels of NAA greatly affected root length, number of roots and its morphology and increasing rooting percentage in tuberose Naz *et al.* (2012). IBA 2.0 mg/l resulted in most effective in rooting of gladiolus (Priyakumari and Sheela, 2005; Hussain *et al.* (1994) and in

tuberose Gajbhiye *et al*. (2011). However, some reports showed lower concentrations of IBA enhanced in vitro rooting of ornamental plants. Beura *et al.* (2005) found that IBA 0.75 mg/l was most effective in gladiolus for *in vitro* rooting. Application of 0.5 mg/l IBA has been registered with highest frequency of root initiation in tuberose (Upadhyay *et al*. 2001; Bindhani *et al.* 2004, Singh *et al.* 2020b). However, higher concentrations of IBA for rooting in microplantlets of tuberose reported by Jyothi *et al*. (2008) where media containing 1.0 mg/l IBA gave maximum number of roots with highest rooting (91.6%). Krishnan *et al.* (2003) found that IBA 4.0 mg/l was favourable for *in vitro* rooting in tuberose. Another rooting hormone like NAA has also been reported for *in vitro* rooting of different ornamental plants. An application of 2.0 mg/l NAA resulted in best rooting in gerbera (Shailaja 2002 and Son *et al.* 2011) while, NAA (0.0–4.0 mg/l) recommended by (Rezende *et al*. 2008) in gerbera. Feng *et al.* (2009) reported best rooting media for *in vitro* gerbera when stem segments fortified with 0.2 mg/l NAA. In tuberose, 1.0 mg/l NAA and 0.5 mg/l NAA suggested for root initiation by Naz *et al*. (2012) and Datta *et al.* (2002) respectively. In gladiolus, Belanekar *et al.* (2010) obtained maximum number of roots and length of roots with 1.0 mg/l IBA while thickness of root was better with 1.0 mg/l NAA. However, in comparison the efficiency of two rooting growth regulators, Emek and Erdag, (2007) observed (20%) rooting with BA (0.1 mg/l) in *Gladiolus anatolicus* and no rooting was observed with NAA (0.5 or 2.0 mg/l). Kundang *et al.* (2017) reported that increased in the concentrations of IAA and α-NAA resulted in maximum root formation. Mateen, (2019) observed that 1.0 mg/l NAA gave 98 percent rooting while IBA induced (96%) root induction. Indole acetic acid (IAA) alone has also been used in various reports for *in vitro* rooting of ornamental and foliage plants. 0.5 mg/l of IAA for *in vitro* rooting in tuberose have been reported by (Nazneen *et al*. 2003; Pohare *et al*. 2012, 2013). Shabbir *et al.* (2012) recommended best rooting with 1.5 mg/l IAA. Taksande *et al.* (2018) employed 2 mg/l IAA and observed highest root proliferation, early root formation and maximum root length. A comperative study carried out by Rajasekharan *et al*. (2000) in tuberose they treated shootlets with 2.5 mg/l IBA responded well with 90% root formation but NAA had maximum response 85% at 3.0 mg/l while number and length of root growth was greater with IBA at 2.0 mg/l. Mishra *et al*. (2005) used IBA and NAA alone *in vitro* rooting of tuberose. 1.0 mg/l IBA induced maximum number or of roots while in application of NAA, 1.0 mg/l gave maximum number of roots. Raghuvanshi *et al.* (2013) employed IBA and NAA alone and IBA in combination with BAP and Kn. 1.0 mg/l IBA was found to be optimum for induction of *in vitro* root proliferating ability, number of root (s) and mean root length as compared to other treatments.

IBA, NAA and IAA in combinations for *in vitro* rooting have been suggested by various researchers. Krishnamurthy *et al.* (2001) obtained 100% root induction, early rooting and maximum number of roots with medium containing IAA 0.25 mg/l and IBA 0.25 mg/l in Shringar and Suvasini cultivars respectively. However, both cultivars showed maximum root length in media containing IBA (0.5 mg/l). Sangavai and Chellapandi (2008) obtained 100% rooting along with the highest average number of roots and longest root in Shringar and Suvasini with combined application of 0.2 mg/l IAA and 0.25 mg/l IBA. Panigrahi and Saiyad, (2013) induced maximum rooting percentage, maximum number of root and length of root with earlier rooting in media containing 0.5 mg/l IAA and 0.5 mg/l BAP. Similarly in tuberose, Panigrahi and Chaudhary, (2013) kept plantlets in a solution containing BAP (0.5 mg l^{-1}) and IAA (2 mg/l) and BAP (0.5 mg/l) and IAA (3 mg/l) at 5^{o}C to induced rooting of Hyderabad Single and Local Double Navsari respectively. Panigrahi *et al.* (2013) treated the shoots with media containing NAA (0.5 mg/l) and IAA (0.5 mg/l) and induced maximum rooting in Phule Rajni while NAA (3.5mg/l) and IAA (0.5 mg/l) found suitable for cultivar Calcutta Double. Panigrahi *et al.* (2013 a) incubated the plantlets in a solution of IBA (0.5 mg/l) and IAA (2.0 mg/l) and IBA (0.5 mg/l) and IAA (2.5 mg/l) for inducing root in Prajwal and Shringar varieties respectively. Ali *et al*. (2015) emerged earlier root initiation with 0.5 mg/l IAA and1.0 mg/l KIN while maximum number of roots and length of root noted with 0.5 mg/l IAA and 1.0 mg/l KIN. Kumari and Pal (2016) obtained higher number of roots in regenerated shoots of tuberose with 0.5 mg/l BAP and 1.5 mg/l NAA. Surendranath *et al.* (2016) initiated highest number of roots in tuberose with IBA (3 mg/l) and NAA

(1 mg/l). Khanchana *et al.* (2019) achieved efficient rooting on media containing 1 mg/l of IBA and 1 mg/l of NAA in four varieties of tuberose.

2. Plant growth promotion and regulation of flowering: Dhiman (1997) noted earlier flowering in *Lilium hybrids* with GA_3 at 100 ppm. Application of GA_3 @ (250 ppm) gave highest number of earlier flower but lowest number of earlier flower obtained from NAA @ 500 ppm. GA_3 caused reduction on bulb yield and bulb weight in tulip (*Tulipa gesneriana* var. Cassini (Ertan and Ali 2005). Parmar *et al.* (2009) observed that the foliar application of GA_3 @ 200 ppm and NAA @ 100 ppm was found most effective in increasing growth and yield of Spider lily. Jamil *et al.* (2015) observed that application of IAA at 60 and 100 ppm and GA_3 at 100, 300 or 500 ppm twice as foliar spray at an interval of 30 days promoted number of bulblets in Hippestrum. However, foliar application of ethrel @ 100 ppm resulted in earlier flower emergence scape and maximum number of flowers per scape. Plants treated with 500 ppm GA_3 produced biggest size of flower and flower scape, highest number of bulblets per plot, bulbs weight per plot along with bulb yield. Porwal *et al*. (2002) observed maximum reduction in plant height, increased number of growth parameters with earlier flowering with CCC @ 2000 ppm when compared to control. In gladiolus, foliar application of NAA @ 100 ppm recorded maximum number of cormels per plant, maximum weight of corm and size of corm in gladiolus (Sharma *et al*. 2004 and Naveen Kumar *et al*. (2008). However, Kumar *et al*. (2008) observed higher number of leaves, leaf length and leaf area with foliar application of NAA @ 500 ppm. NAA @ 150 ppm recorded larger size corm and heavier corm in cv. White Prosperity Kumar *et al*., (2009). NAA @ 300 ppm recorded the maximum corms per plant, maximum diameter of corms per plant and weight of corms per plant as reported by Chopde *et al*. (2012). Patel *et al*. (2011) obtained maximum yield of corms and cormels with CCC @ 250 mg/l while maximum number of florets with 1000 ppm CCC recorded by Kumar *et al.* (2008a). Maniram *et al*. (2012, 2012 a) noted that foliar application 50 ppm of salicylic acid had maximum plant height, rachis length and floret diameter in gladiolus. Pal *et al.* (2015) found maximum growth and flowering parameters with earlier flowering with 100 ppm salicylic acid. An application of GA_3 @ 100 ppm significantly increased growth and flowering parameters in gladiolus (Rana *et al*. 2005). Sable *et al.* (2015) observed maximum growth and flower parameters in gladiolus with GA_3 200 ppm foliar spray. Hesami and Dolatkhahi (2016) examined the effects of two different methods of application (foliar spray and drench) and various concentrations of gibberellic acid (GA_3), salicylic acid (SA), mival (MI) and krizatcin (KR) on vegetative and reproductive features of *Gladiolus hybridus*. The maximum floral stalk length was noted with 50 mg/l GA_3 spray while maximum floret diameter was achieved at 100 mg/l MI applied as foliar spray. The maximum number of florets obtained from the plants treated with intermediate concentrations of MI in both application methods. Corms drenched with 25 mg/l MI effectively increased corm weight and volume. Singh *et al.* (2013) revealed maximum length of leaf and width of longest leaf with GA_3 at 400 ppm on gladiolus cvs. Sabnum and Gunjan. 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. In tuberose, Devadanam *et al.* (2007) recorded minimum days for spike emergence, maximum spike length, length of florets, diameter of floret and maximum vase life of spikes in tuberose with foliar spray of GA_3 @ 150 ppm. Foliar application of salicylic acid at lower concentration significantly emerged earlier spike in and also increased the vegetative growth and flowering parameters of tuberose (Anwar *et al.* 2014). In chrysanthemum, GA_3 150 ppm emerged earlier flowering with maximum flower yield (Dahiya and Rana 2001, Mohariya *et al.* 2003) and maximum vase life of chrysanthemum (Moond and Geholt 2006). An examination of different growth regulators study conducted by Gautam *et al.* (2006) who used different growth regulators *viz.*, GA_3 (50, 100, 150 and 200 ppm), NAA (50, 100, 150 and 200 ppm), Ethrel (750, 1000, 1250 and 1500 ppm) and B-nine (1000, 1500, 2000 and 2500 ppm) on growth, flowering and yield of chrysanthemum cv. Nilima. Among the different chemicals, GA_3 @ 200 ppm have significantly influenced the vegetative growth and flowering parameters. However, Kumar *et al.* (2010) used GA_3, Ethrel and control with (distilled water). GA_3 at all concentration caused early flowering, maximum growth and flowering with

longer duration of flowering, while ethrel at all concentration reduced plant height, increased number of main branches, basal diameter of stem and caused late flowering than control. Rakesh *et al.* (2004) examined the GA_3 effect in chrysanthemum cultivars viz; Flirt and Gauri. Both cultivars produced maximum yield with 200 ppm GA_3. Sainath *et al.* (2014) concluded that 200 ppm GA_3 as foliar spray significantly increased number of capitulum per plant, capitulum diameter, number of seeds per capitulum, dry weight of capitulum, 1000 seed weight and seed yield (per plant and per ha) as compared to control. Ashutosh *et al.* (2019) sprayed plants with salicylic acid @100 ppm under integrated nutrient management system and noted improvement in growth and flower yield. In marigold, Singh (2004) observed that foliar spray of GA_3 @ 100 ppm resulted in maximum plant height whereas, 50 ppm kinetin produced maximum number of leaves/plant and leaf area index. Tyagi and Kumar (2006) recommonded 200 ppm GA_3 for maximum growth and flower yield parameters in French marigold. Foliar application of GA_3 100 ppm resulted in maximum growth flowering and economic parameters of marigold as reported by (Tiwari *et al.* (2018, 2018a). However, Pal *et al.* (2018) sprayed marigold plants with 300 ppm GA_3 resulted in maximum plant height, plant spread while 400 ppm MH showed minimum plant height however, Etheral @400 ppm had maximum number of branches. Mujadidi *et al.* (2019) observed maximum growth and flowering in marigold when plants sprayed with GA_3 300 ppm at 40 days after transplanting. Foliar application of salicylic acid at lower concentration significantly emerged earlier spike in and also increased the vegetative growth and flowering parameters in African marigold (Pacheco *et al.* 2013; Choudhary *et al.* 2016; Basit *et al.* 2018). In rose, Bhattacharjee and Singh (1995) sprayed the plants with Daminozide (B-9) and noted increase in primary and secondary shoots, stimulated diameter of the shoots at base while Daminozide at 500 ppm resulted in increased bud size but did not show any significant difference with number of petals and longevity of flowers when compared to control. In carnation, Verma (2003) observed that application of GA_3 at 100 ppm had maximum plant height, buds size, number of flowers per plant and GA_3 @ 200 ppm registered maximum flower yield per plant and yield per hectare in. Prashanth *et al*. (2006) sprayed plants with GA_3 @ 200 ppm exhibited maximum elongated shoots and internodes length with reduced shoot diameter and number of laterals. Safari *et al.* (2004) noticed that treatment of NAA, Alar and Cycocel increased the number of flowers in plants as compared to other treatments and control in *Rosa damascene* Mill. Flowering plants like Iris, Taha, (2012) sprayed the plants with GA_3 @ 250, 500 and 750 ppm and CCC @ 250, 500 and 1000 ppm and Alar @ 125, 250 and 500 ppm. GA3 @ 750 ppm significantly increased vegetative growth characters and it also influenced the days to flowering, maximize the flower stalk characters, bulbils parameters, total chlorophyll and carbohydrate content. In Gaillardia, Ghadage *et al*. (2010) reported that the foliar application of NAA @ 100 ppm increased size of flowers but higher concentration of NAA decreased the flower size. Kadam *et al.* (2020) emerged earlier flowering, 50% flowering and longest flowering duration in gaillardia with GA_3 @ 200 ppm. Girisha *et al*. (2012) observed that application of NAA @ 150 ppm significantly increased the plant height and plant spread in Daisy plant. Bhardwaj *et al*. (2020) drenched the *Barleria cristata* L. 'Alba' plants with three levels of each BA and paclobutrazol i.e. 0 ppm, 100 ppm and 200 ppm each used as foliar spray. Application of BA @ 200 ppm and paclobutrazol @ 200 ppm had maximum values for number of side shoots per plant number of leaves per plant number of flower clusters per plant number of flowers per cluster number of flowers per plant opened at a time and duration of flowering. However, maximum pot plant height and plant spread along with other pot with the application of double pinching, paclobutrazol and BA @ 100 ppm each. In China aster, an application of 200 mg/l GA_3 resulted in maximum growth and flowering parameters (Kadam *et al.* 2002; Kumar *et al*. 2010; Kumar *et al*. 2015; Mamilla Sindhuja *et al*. 2018). Kumar *et al.* (2003) examined the effect of GA_3 on four cultivars of China aster, *viz.*, Kamini, Poornima, Shashak and Violet cushion. Kamini demonstrated better performance in most of the characters with 200 ppm GA_3. Kumar *et al.* (2018) recorded maximum growth and flowering parameters in China aster with the application of GA_3 300 ppm. Lee *et al.* (2021) treated the clones of Phalaenopsis Queen Beer 'Mantefon' with no

hormones (control), GA_3 100 mg/l, GA_3 200 mg/l, BAP 100 mg/l, and GA_3 100 mg/l + BAP 100 mg/l by foliar spray. All exogenous hormonal treatments did not induce inflorescence initiation, but lateral shoots were observed in BAP-treated plants even though this plant is a monopodial orchid. Application of GA_3 significantly increased leaf length and decreased leaf width, and consequently increased length: width (L:W) ratio compared to control and BAP alone. Clones treated with GA_3 increased stem length and decreased stem diameter. BAP accelerated inflorescence emergence and significantly increased inflorescence numbers, whereas GA_3 and GA_3 + BAP slightly delayed inflorescence emergence.

It has been reported by various workers that pre-plant soaking of plant material in PGRs is an efficient method but relatively less use on commercial scale (Ranwala *et al*. 2002; Sajjad *et al*. 2015). Soaking of gladiolus corms with GA_3 @ 200 ppm significantly produced higher plant height with maximum spike length, number of florets per spike and yield spikes per ha as reported by (Havale *et al.* 2008). Corms of gladiolus cv. American Beauty dipped in 125 ppm solution emerged earlier and 50% sprouting as compared to control Suresh *et al.* (2009). Kumari *et al.* (2011) found maximum number of leaves per plant in gladiolus with GA_3 100 ppm which was statistically at par with GA_3 50 ppm however, more number of leaves per plant noted with minute higher level of solution (150 ppm) as reported by Kumar and Singh (2005). Misra *et al.* (1993) also reported GA_3 application enhanced vegetative growth and flowering. Plant height and spike length increased by application of GA_3 (100 ppm) as observed by Bhalla and Singh (2000). In another study, Bhalla and Kumar (2007) treated the corms with GA_3 300 ppm and obtained maximum plant height and maximum number of leaves per plant. Rana *et al.* (2005) reported that gladiolus corms dipped with GA_3 at 100 ppm resulted in earlier flowering but untreated plant started flowering later than those of treated one. Number of florets per spike was also increased with increasing concentrations of GA_3 while maximum number of spikes was recorded under GA_3 at 150 ppm as reported by Singh *et al.* (2007). In tuberose, De and Dhiman (2001) soaked the bulbs with higher levels of GA_3 (200 – 500 ppm) and noted earlier spike initiation and flower opening by 65 – 70 days and 22 – 24 days respectively as compared to control with maximum number of spikes per square meter. Tiwari and Singh (2002) optimized soaking concentration of GA_3 at 200 ppm for increased the spike length, number of spike and number of leaf per clump. Singh *et al.* (2008) dipped tuberose bulbs with 200 ppm GA_3 for 12 hours resulted in earliness in days to spike emergence and maximum spike length, number of florets per spike, number of spikes per clump and spike weight in cv. Single. Bulbs dipped in NAA @ 100 ppm was found to be the most effective in increasing the spike length, number of rachis and flower yield in tuberose (Sarkar *et al.* 2009). Dhumal *et al.* (2018) dipped bulbs in 160 ppm GA_3 for 24 hours before planting followed by spraying of plants with 160 ppm GA_3 and soaking of bulbs in 80 ppm IBA and spraying of plants with 80ppm IBA resulted in maximum growth and flowering in tuberose. Tulip bulb soaking at 100 mg/l gibberellic acid (GA_3) increased bulb sprouting percentage, fresh and dry weight of leaves (Ramzan *et al.* 2014). In *Lilium longiflorum*, Emami *et al.* (2011) soaked the bulbs for 24 hours in solution of gibberellic acid and 6-Benzyladinine with different concentration and planted in a green house condition. Application of GA_3 @ 75 ppm and 6-Benzyladinine @ 75 ppm resulted in increases the anthocyanin, chlorophyll content, and vase life respectively. Plants fortified with GA_3 significantly promoted new leaf development. Anu *et al.* (2005) examined the effect of different concentration of GA_3 (100, 150 and 200 ppm) for 8, 16 and 24 hours before planting of Chincherinchee plants and noted that plants treated with GA_3 @ 150 ppm for 24 hours recorded the best for plant height, plant spread, leaf area, number of scapes/bulb and flowering and maximum longevity of the whole spike, however GA_3 @ 1000 ppm concentration envisaged the maximum plant height.

Brassinosteroids (BS) are a new and unique class of plant growth regulators which have also been employed in ornamental plants. Badawy *et al.* (2017) reported that zinnia plants treated with 24-epibrassinolide (EBR) 10^{-8} with sodium silicate 50 ppm increased plant growth. In gladiolus, BR at 10 mg/l significantly increased the number of leaves and leaf areas, spike length, number of florets, and vase life (Padmalatha *et al.* 2013). In another study, Padmalatha *et al.* (2015) noted that

foliar sprays of BR (10 ppm) and GA_3 (150 ppm) significantly increased number of corms per plant, corm size, corm weight, and propagation coefficient followed by TIBA (100 ppm). BR (10 ppm) and TIBA (100 ppm) produced maximum number of small cormels per plant. Maximum weight of cormels per plant observed with BR (10 ppm) and GA_3 (150 ppm). Mollaei *et al*. (2018) primed corms and foliar sprayed on plant with concentrations of 0.5, 1, and 2 μM 24-epibrassinolide (EBR). Highest levels of corm sprouting and flower spike emergence were noted with 1 μM EBR. Maximum floret numbers, flower spike fresh and dry weight and vase life showed observed with 1 μM EBR combined treatments. The combination of corm priming at 2 μM and foliar spay at 1 μM EBR, showed the highest effect on malondialdehyde reduction. The highest activities of antioxidant enzymes such as catalase, peroxidase, and superoxide dismutase were obtained in combination of 1 μM EBR corm priming and 1 μM EBR foliar spray. EBR treatments also prolonged vase life from 8 to 14 days and significantly improved gladiolus morphological and biochemical traits. Mollaei *et al.* (2018) assessed genetic analysis of primed corms and showed that around 20% of genes are differentially-expressed in primed seeds compared to the control. Lotus root slices were soaked in EBR for 2 min before storing for 8 days and noted that the treated portions had 33% less MDA compared to the control. The activities of antioxidant enzymes such as POD, CAT, APX were higher than the control by 28, 52, and 25%, respectively (Gao *et al.* 2017).

Polyamines are also comes under new group of plant growth regulators and now a day used for various purposes in flowering and foliage plants. Mahros *et al.* (2011) reported that foliar application of putrescine at the rate of 100, 200, or 300 mg/l improved flowering period, yield, stem and inflorescence length, fresh and dry weight in chrysanthemum. In addition, foliar application of 250 mg/l putrescine showed higher plant height, leaf number, and leaf fresh and dry weight in the vegetative stage of wallflowers (Youssef 2007).

Jasmonic acid (JA) and methyl jasmonate (MeJA) are endogenous plant growth substances that play an important role in plant growth and development. Methyl Jasmonate (MeJA), a methyl ester of Jasmonic acids is a fragrant volatile compound isolated from the flowers of *Jasminum grandiflorum* (Jong-Joo Cheong and Yang Do Choi 2003). Very little work on Jasmonic acid (JA) and methyl jasmonate (MeJA) has been carried out on flowering and foliage plants. In gladiolus, Sewedan, et al. (2018) noted that combination of salicylic acid at 150 ppm and methyl jasmonate at 75 ppm resuled in improve the vegetative growth and flowering characteristics. However in rose, Jahanbazi *et al.* (2014) observed that salicylic acid (SA) at 14 ppm resulted in maximum number of flower, diameter of stalk and total chlorophyll contents while maximum flower diameter, stalk length and fresh weight was recorded with 21 ppm. Among the doses, Jasmonic acid (JA) 50 ppm as foliar application showed best dosage.

Plant growth regulators have also been used in ornamental grasses. It has been reported by various researchers that PGR application can modify plant shape and foliage colour (McCullough *et al.* 2005; Taiz and Zeiger 2006; McElroy and Martins 2013; Głąb *et al.* 2020). Hussein *et al.* (2012) noted that *Paspalum vaginatum* turfgrass plants grown under shade level up to 42% did not show any reduction in growth. However, shade level exceeds 42% (up to 70%) with paclobutrazol at 1500 ppm or trinexapac-ethyl TE at 400 ppm as foliar application monthly showed adverse effects of shade. Bryant *et al.* (2016) noted that one application of GA increased DM yield by increasing perennial ryegrass. A single GA application in late winter resulted in increased fibre and reduced protein concentration in ryegrass. Abdullah *et al.* (2017) soaked the seed of four turf grass seeds genera including Bermuda grass (*Cynodon dactylon* L. var. cd4), Tall fescue grass (*Festuca arrundaceae* L. var. Barleroy), Kentucky blue grass (*Poa pratensis* L. var. Baron) and Perennial Rye grass (*Lolium perenne* L. var. Barlennium) in five concentrations (0, 50, 100, 200 and 400 mg/l) of gibberellic acid (GA_3). GA_3 400 mg/l resulted in better growth as compared to other treatments. Araújo *et al.* (2018) reported that the application of GA_3 50 μM increased in height of Tifton 85 bermudagrass in the first crop cycle as compared to second crop cycle. The same concentration of GA_3 produced higher dry matter yield and removal of nitrogen, phosphorus, and sodium for the first crop cycle in CWs. However, in the second crop cycle, the application of GA_3 had no effect on dry

matter production and nutrient removal by Tifton 85 bermudagrass in CWs. Glab *et al.* (2020) observed that gibberellic acid application resulted in lighter leaves with higher yellow hue and in a lower score of overall appearance and turf colour assessment. Paclobutrazol and Trinexapac Ethyl had a beneficial influence on colour characteristics and turf quality. Flurprimidol and Melfuidide did not show effect on turfgrass colour and quality after PGR treatment. The changes in colour of turf of perennial ryegrass correlated with PGR rates. Higher rates of PGRs resulted in increased intensity of discolouration. Lima *et al.* (2020) reported that application of paclobutrazol controlled Bahiagrass growth when applied at 2.2 Kg ha^{-1} in regular applications of 30 to 45 days however it affected the density and consequently the aesthetics of the turfgrass. Melero et al. (2020) observed that paclobutrazol dose of 2 ml L^{-1} reduced fresh mass, without changing the concentration of leaf chlorophyll and green colour. Phenoxaprope-P-ethyl, on the other hand, had an effect as a growth regulator for the studied species, when used in the dose of 6.25 μL L^{-1}.

3. Apical dominance/ Enhancing lateral branching: To overcome the apical dominance, the routine is pinch or stop the main shoot which enables production of lateral shoots, e.g. carnation, chrysanthemum. It can also achieve by the use of PGR's like MH (600 or 1000 ppm), ethephone (Florel), benzyladenine *etc.* which promotes branching (lateral shoots) equal to that obtained through pinching. Henny (1986) sprayed the plants of Dieffenbachia with BA at 500, 1000 or 2000 ppm and found increased lateral shoot development. Plants treated at all BA levels showed an average of 6 lateral shoots as compared to 2 for untreated plants. Plant height was unaffected by BA-treatment. Ethephon and dikegulac were also tested at the same rates as BA but did not show any effect on lateral shoot development. Henny and Fooshee (1989) treated anthurium plants with 250 or 500 ppm BA and observed that BA had more basal shoots, shorter height and smaller leaves than control plants. Application of paclobutrazol either as drenching or foliar spray resulted in an increase in the number of lateral shoots per plant in *Bougainvillea spectabilis* Willd. (Karaguzel 1999) but spray treatments increased and media drenches reduced lateral shoot production in *B. glabra* 'Sanderiana' as reported by (Karaguzel and Ortacesme, 2002). In zinnia, Ali *et al.* (2021) noted that BAP application (@100 $mg.L^{-1}$) reduced height of plant, enhanced number of flowers per plant at lateral branching.

4. Seed set and yield: PGRs play an important role in seed set and improvement in yield of various flowering crops. In marigold, Singh, (2004) reported that plants sprayed with GA_3 at 200 ppm increased number of seeds/flower while GA_3 @ 100 ppm and kinetin @ 100 ppm produced less number of seeds/ plant. However, plants sprayed with GA_3 @ 100 ppm increased seed weight/ flower and weight of 100 seeds followed by 200 ppm GA_3 and 100 ppm kinetin. Maximum seed yield/ plant recorded with GA_3 @ 100 ppm, which was statistically at par with GA_3 @ 200 ppm and IAA @ 100 ppm. Sunitha, (2006) noted that plants sprayed with NAA increased the 1000 seed weight and germination percentage as compared with control in African marigold, (*Tagetes erecta* Linn.). Sainath *et al.* (2014) sprayed the plants with GA_3 @ 200 ppm and significantly increased number of seeds per capitulum, 1000 seed weight and seed yield (per plant and per ha) as compared to control. Similarly, tricontanol @ 1000 and 500 ppm, mepiquat chloride @ 1000 and 2000 ppm and cycocel @ 1000 ppm and 2000 ppm also significantly improved the 1000 seed weight and seed yield (per plant and per ha) as compared to control. The seed quality parameters such as germination percentage, seedling length, vigour index and seedling dry weight were higher with lower electrical conductivity with GA_3 @ 200 ppm. Kumar *et al.* (2015) obtained maximum seed yield per plant (9.85 g) and seed yield per hectare (1489.65 kg) with 200 mg/l GA_3 in China aster. Kumar *et al.* (2020) observed that foliar spray of 250 ppm gibberellic acid enhanced growth, and improved seed yield and quality parameters of marigold

5. Dormancy breaking: The chemicals like ethylene chlorohydrins or Ethera, Ethephon, Thiourea, Hydrogen cyanamide (Dor-break or Dormex) are used for breaking the dormancy of seed and bulbs. Malik *et al.* (2009) reviwed the causes of dormancy in gladiolus bulbs and reported the dormancy in gladiolus especially due to abscicic acid. However, it has also been reported that fatty acids like linolenic acid and ferulic acid also act in conjunction with ABA in imposing dormancy. Kumar *et al.* (2009)

dipped the corms in growth regulator solutions for a period of 10 hours before planting after removal of corm scales. GA_3 at 125 ppm recorded less number of days to sprout and 50 per cent sprouting of gladiolus corms. All treatments at higher concentrations recorded minimum number of days to sprouting and 50 per cent sprouting of gladiolus corms. Kumar *et al*. (2010) revealed that 24 hours corm soaking with GA_3 @200 ppm emerged earlier flower showing colour, full opening of first florets and full opening of last floret in gladiolus cv. Candyman. Padmalatha *et al.* (2013a) observed that salicylic acid (SA) 150 ppm emerged earlier sprouting over control while TU 2%, SA 150 ppm, KNO_3 1.5% and GA_3 150 ppm significantly increased sprouting percentage of corms over control and recorded maximum number of sprouts per corm. Bhujbal *et al.* (2014) treated corms with GA_3 125 ppm and cold storage duration 24 week was found most effective in the breaking of dormancy and found in earlier sprouting.

6. Post-harvest handling of flowers: Post-harvest handling is a process that starts by flower lovers, growers as well as farmers. It involves many treatments are given to the flowers without delay after harvest to enhance their vase life which fulfills florist as well as consumer demands and ultimately gives higher turnover. Various factors are affected post harvest quality of flowers including pre-harvest of flowers viz: genetic makeup of flowering plant, growing conditions, light, temperature, humidity, carbon dioxide and post harvesting factors like temperature, humidity, water quality, conditioning, pre-cooling, flower preservatives/ chemicals, refrigerated storage, grading, packing and transport etc. (Verma and Singh 2021). Each flower parts play an important role and should be used when needed. Flowers require a lot of energy to maintain their freshness, which can be seen as worthless because they have completed their useful role in the plant's life. Ethylene plays an important role in flower senescence. Flower senescence means the last stage of floral development and wilting of flowers or abscission of whole flowers or flower parts . Changes in ethylene level, its perception, and the hormonal crosstalk directly or indirectly regulate the life of detached flower. However, through floral senescence, flowers are removed from their main parts of plants resulting in nutrients redistributed to the growing part of the flower (e.g., ovary) or the other organs of the plant. In some flowers like *Petunia hybrida*, *Dianthus caryophyllus*, *Mirabilis jalapa*, and carnations (*Dianthus caryophyllus* cv. Barbara) ethylene plays a major role in senescence and also known as ethylene- sensitive ornamental flowers (Xu *et al*. 2007; Ichimura and Niki 2014). Senescence occurs due to degradation of nucleic acid, both ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) within the nucleus, mitochondria, and plastids Kladnik *et al*. (2004). Abscisic Acid (ABA) promotes the senescence of cut flowers and flowering potted plants (Ferrante *et al.* 2015). However, Müller *et al.* (1999) observed that application of Abscisic acid increased the sensitivity of rose to ethylene while Trivellini *et al.* (2015) found that BA treatment delayed senescence by reducing the Abscisic acid (ABA) content and higher ethylene production. Yin *et al*. (2015) reported that reduced bioactive GA increases ethylene-mediated flower senescence in petunia. However, earlier Chang *et al*. (2003) noted increasing flower longevity in transgenic petunia by the over-production of cytokinins which delayed corolla senescence and decreases sensitivity to ethylene. Lu *et al*. (2014) showed that *RhHB*1 gene expressed in senescing petals, and its expression was induced by ABA or ethylene in petals while gibberellins GA_3 delayed the process. However, silencing of *RhHB*1 delayed the ABA- or ethylene-mediated senescence, and resulted in higher petal anthocyanin levels and lower expression of *RhSAG*12. Salleh *et al*. (2016) detached flowers of *Erysimum linifolium* (wallflower) from plants and noted ethylene production reached its highest level however, application of exogenous application of cytokinins or 6-methyl purine (an inhibitor of cytokinins oxidase) causes delays in floral senescence.

The vase life of cut flowers can be prolonged significantly by exogenous applications of kinetins, ethylene inhibitors in the vase water. In gladiolus, Kumar *et al.* (2007) kept gladiolus spikes in sucrose 20% + STS 200 ppm + GA_3 300 ppm pmwas found superior for prolonging self life of gladiolus spikes. Zulfiqar *et al.* (2020) noted longest vase life in gladiolus/sword lily with *Moringa oleifera* leaves (MLE) extract with combination with 50 mg/l salicylic acid (SA) or 50 mg/L gibberellic acid (GA). Saeed *et al.* (2016) used salicylic acid

(SA) in various concentrations, viz., 0, 50, 100, 150 and 200 mg SA/l in vase solution. Salicylic acid at 150 mg/l significantly increased the days to open florets, percent florets opened, retained higher fresh weight, and enhanced the SOD, POD, CAT and free radicals scavenging activity. Kumar, (2015) noted that gladiolus spikes pulsed with 20% sucrose + 300 ppm Al_2SO_4 + 200 ppm GA_3 attained maximum number of floret, floret weight and floret open at a time during the study. Kumar *et al.* (2007) pulsed gladiolus spike in holding solution containing 20% sucrose + 300 ppm STS + 300 ppm GA_3 for prolonging self life of gladiolus. Kumar et al. (2008) noted in increase longevity of gladiolus spikes under kept in solution containing sucrose 20% + Sodium thiosulphate 200 ppm + GA3 400 ppm. Raj *et al*. (2013) pulsed gladiolus spikes with 4% sucrose + 200 ppm salicylic acid and observed maximum fresh weight and dry weight of flowers. Padmalatha *et al.* (2015) reported that pre-harvest foliar spray of GA_3 (150 ppm), BR (10 ppm) and CPPU (5 ppm) induced earliest first-floret opening and recorded maximum value for number-of-florets open at a time per spike, diameter of second fully-opened floret and vase-life of flowers. Saeed *et al.* (2014) observed that the application of GA_3 at 25–50 mg/l resulted in improving the vase life and quality of gladiolus cut flowers. Ahmad (2015) noted that marigold and petunia kept under 40–80 mg/l ancymidol provided ample growth control with darker green foliage; however, postharvest longevity was extended only when plugs were sprayed with 160 mg/l ancymidol. During simulated storage and shipping, plant growth retardants maintained darker green foliage for potted sunflower, zinnia, and marigold plugs and prevented postharvest stem elongation of petunia plugs. Parmar *et al.* (2009) noted that spider lily spikes obtained from all the levels of CCC @ 1000, 750 and 500 ppm were found most effective in increasing shelf and vase life of flowers. Dias- Tagliacozzo *et al.* 2003; Dias-Tagliacozzo and Castro 2001) reported that addition of 50 ppm of gibberellic acid in solution as pulsing delayed leaf senescence in lily and aster. However, Brackmann (2005) who evaluated the effect of GA_3 on three varieties of chrysanthemums and noted the promotion of senescence of both leaves and flowers.

Polyamines are also comes under new group of plant growth regulators and now used for prlonging self/vase life of flowers. Polyamines are known for their anti-senescence effects during ageing sequence of plant tissue by retarding ethylene synthesis by inhibiting ACC synthesis in cut carnation (Lee *et al.* 1997). Application of spermidine in vase solution significantly delayed the senescence by disrupted ethylene mechanism in carnation cut flowers (Tassoni *et al.* 2006). Foliar applications of polyamines increases vegetative growth in carnation and dahlia (Mahgoub *et al*. 2006, 2011), gladiolus (Nahed *et al*. 2009) as well as the chlorophyll content in leaves in gladiolus (Nahed *et al*. 2009) and chrysanthemum (Mahros *et al*. 2011). Polyamines with in combination of sucrose as holding solutions extended the vase life of cut flowers of gladiolus (Singh *et al.* 2005), carnation and gerbera (Bagni and Tassoni 2006). Dantuluri *et al.* (2008) noted that polyamines with sugar in holding solution significantly improved fresh weight, uptake of vase solution, flower opening and vase life in gladiolus. Polyamines delayed senescence and improved vase life of cut spikes by improving membrane stability. Exogenous applications of spermidine (Spd) and spermine (Spm) treatments resulted in increase the PAs content in cut flowers and delayed their senescence and improve quality (Yang and He, 2001). However, a combination of GA_3 + Spm spray delayed the senescence of cut flowers in *Anthurium andraeanum* (Simões *et al.* 2018). In bougainvillea, Lin *et al.* (2021) noted that polyamine treatments acted differently on bract longevity and endogenous 1-aminocylopropane-1-carboxylic acid (ACC) content, and each combination and single polyamine was not equally significant in regard to coordinating a response to ACC regulation. Spermine at 1 mmol/l resulted in prolongs the vase life and decreased the production of ethylene in carnation flowers (Lee *et al.* 1997) while application SPM in rose cv. Dolcvita did not promote the vase life extension (Farahi et al., 2013). Farahi *et al.* (2018) noted that PAs and CS increased quantitative and qualitative characteristics of rose flower 'Dolce Vita' under in soilless culture system due to the increased uptake of minerals. Application of spermine 5 mM increased the vase life of *Gladiolus* flowers by 3 days as compared to control treatment (Sivaprakasam *et al.* 2009). However, the application of spermidine 0.1 mM in combination with sucrose 2%, calcium 200 mg/l, penicillin 100 mg/l, calcium nitrate 0.15% resulted in delayed senescence process and

prolonged the vase life of rose flowers (Xiao Ling *et al.* 2007). Favero *et al.* (2020) observed that spraying BAP at concentrations of 37.5–300 mg/l improved postharvest durability of *Anthurium andreanum* 'Apalai' flower without inducing spathe blueing as compared to pulsing.

7. Plant height control and delayed flowering: Growth retardants like maleic hydrazide, SADH, CCC, B-nine, triazoles, ethopon, paclobutrazol etc have been used for height control of ornamental and foliage plants (Pinto *et al*. 2005, 2006; Kumar *et al*. 2010; Ahmad 2015; Malik *et al*. 2017). Most of the growth retardants are specific in their action and particular growth retardant may showed effect only a particular plant species while it may not be effective for others. An ideal growth retardant should be universally effective in plants, non-phytotoxic and prolong the post-harvest life without leaving any harmful/toxic residual effect. Many growth retardants are available commercially for ornamental horticulture production. Among the growth retardants in ornamentals, paclobutrazol have been widely used by various researchers as well as nurseryman (Karaguzel and Ortacesme 2002; Karaguzel *et al*. 2004). Blanchard and Runkle (2007) dipped Argyranthemum (*Argyranthemum hybrida* 'Sunlight'), calibrachoa (*Calibrachoa hybrida* 'Callie Dark Blue'), petunia (*Petunia hybrida* 'Cascadias Vivid Red'), scaevola (*Scaevola albida* 'Jacob's White'), and verbena (*Verbena hybrida* 'Rapunzel Red') liners in paclobutrazol at 4, 8, or 16 mg/l or in uniconazole at 2, 4, or 8 mg/l for 30 seconds followed by transplanted. All concentrations of paclobutrazol and uniconazole inhibited stem elongation by 21% to 67% in calibrachoa, petunia, scaevola, and verbena. However, in argyranthemum, shorter stems were (33% to 42%) noted from the plants treated with paclobutrazol at 8 or 16 mg/l or uniconazole at all rates.

However, in some ornamental plants, paclobutrazol has effectively increased the number of flowers like *Bougainvillea glabra* (Karaguzel and Ortacesme 2002), *Calendula officinalis* (Mahgoub *et al.* 2006a), *Dendrobium* orchids (Te-chato *et al.* 2009) and *Consolida orientalis* (Mansuroglu et al. 2009). In *Lantana camara,* Matsoukis *et al*. (2001) found maximum number of flowers per plant with drenched paclobutrazol concentration 80 mg/l but higher concentrations resulted in a decrease in the number of flowers per plant. Higher concentration of paclobutrazol at 250 mg/l increased the number of flowers compared to control treatments in *B. glabra* and *L. varius* as reported by (Karaguzel and Ortacesme 2002; Karaguzel *et al*. 2004) respectively. Kumar *et al.* (2010) noted that ethrel at 100 and 200 ppm increased the number of flower per plant, diameter of flower, fresh weight of flower and flower yield per plant than control. Ahmad Nazarudin (2012) employed growth retardants such as paclobutrazol (0.25 g/l), uniconazole (2 mg/l) and flurprimidol (0.02 mg/l) for growth and flowering of potted *Hibiscus rosa-sinensis*. Paclobutrazol significantly reduced the plant height and leaf area, increased the chlorophyll content and number of flower buds but delayed the blooming. Uniconazole was found to be more effective in promoting flowers and increased the root length as compared to the controls. Sainath *et al.* (2014) examined various growth retardants efficiency out of which, mepiquat chloride @ 1000 ppm recorded significantly higher germination percentage, seedling length, vigour index and seedling dry weight with lower electrical conductivity followed by mepiquat chloride @ 2000 ppm, cycocel @ 1000 and 2000 ppm. In China aster, Kumar *et al.* (2018) noted maximum number of days taken for opening of first flower with the spray ethrel 200 ppm. Ahmad (2015) assessed the effects of paclobutrazol and ancymidol on potted sunflower (*Helianthus annuus* L.), zinnia (*Zinnia elegans* Jacq.), marigold (*Tagetes erecta* L.) and petunia (*Petunia hybrida* Vilm.) plugs, respectively. Paclobutrazol was applied as a drench at 0, 1.0, 2.0, or 4.0 mg of a.i. per 15.2-cm pot for sunflower and 0, 0.5, 1.0, or 2.0 mg per 12.5-cm pot for zinnia, while ancymidol was applied at 0, 40, 80, and 160 mg/l as a foliar spray for marigolds or petunia plug crops. Increase paclobutrazol dose or ancymidol concentration controlled plant growth (plant height and diameter, shoot fresh or dry weight) for all species tested. Malik *et al.* (2017) noted that MH 1000 ppm was very effective in reducing plant height, increased in leaf number, stem diameter, primary and secondary branch number. Maximum days to flower bud appearance and colour break, maximum flower diameter, flower fresh weight and minimum peduncle length in dahlia noted with ethephon 1000 ppm. Highest flower number was recorded with MH 500 ppm while maximum flower bud diameter with MH 1000 ppm. Abrol *et al.* (2018)

grown plants of chrysanthemum cv. UHFSChr-Collection-1 under natural photoperiod and sprayed with daminozide 3000 ppm and paclobutrazol 60 ppm. Both retardants under controlled photoperiod had highest quality pot mum production of chrysanthemum. Qureshi *et al.* (2018) observed that cycocel treated plants recorded a significant increase in fresh and dry mass of whole plants, whereas B-nine treated plants were comparable with the controls. Cycocel and B-nine treated plants showed early emergence of buds and inflorescences whereas no significant effect was recorded on number of laterals. Cycocel application resulted in the increase in inflorescence number of chrysanthemum. In gaillardia, Dhanasekaran *et al.* (2018) sprayed the plants with MH 600 ppm showed reduced in plant height, maximum number of branches, number of leaves, plant spread, earlier flower initiation, maximum number of flowers per plant and higher flower yield per plant. However, CCC at 750 ppm recorded the maximum individual flower weight and flower diameter. Currey and Erwin (2012) noted that paclobutrazol and uniconazole exhibited broad efficacy with respect to inhibition of stem elongation across all 11 species of kalanchoe. However, benzyladenine and ethephon increased the number of branches for several species. Aljaser and Anderson (2021) soaked gladiolus corms in ancymidol (0, 100, and 400 $mg.L^{-1}$). All ancymidol concentrations had significantly fewer flowers or were completely nonflowering under higher concentrations. Treated genotypes had increased leaf width as ancymidol concentration increased. Conversely, flower stalk heights were shorter as the ancymidol concentration increased while the number of stalks was nonsignificant. Corms, cormel number, and fresh weights decreased in all genotypes.

CONCLUSION

PGRs have been used for enhancing flower production in various ornamental plants under field condition. Small quantity of PGRs can manipulate plant growth, flowering pattern in ornamental plants and also increase flower yield under field condition by physiological process of plants. PGRs are also helpful to initiation of rooting in cuttings as well as *in vitro* rooting of flowering and foliage plants. PGRs are also involved in *in vitro* protocol of various flowering and foliage plants. Plant growth regulators and new class PGRs have been very effective in enhance lateral branches, prolonging self life/vase life of flowers, breaking of dormancy in seed/bulbs/corms/tubers in various ornamental plants. Growth retardants can be helpful to change plant growth and provide desirable shape of plant.

Future prospective: Ornamental plant production has changed drastically in the last twenty years in world. Now a day, 145 countries are involved across the world in production of ornamental and foliage plants including western countries like Netherlands, USA, Columbia and Italy as leading growers and traders. Netherlands continues to be the global leader of floriculture trade with having 43.7% of total world exports during 2018. The demand for fresh flowers and foliage plants has steadily increased not only for decoration but also for many other purposes like essential oils, cosmetics, aroma therapy, dry flowers, potpourries, natural dyes, medicines, etc. Therefore, special attention should be made for increasing ornamental production. Application of plant nutrients play an important role in production in ornamental plants but under changing climatic scenerio, application of some new class plant growth regulators and discovery of new PGRs can be helpful to manipulate growth, prolonging vase life/self life and flower production of various ornamental crops. Therefore, more research should be carried out on new class PGRs such as polyamines, Brassinosteroids (BS) and Jasmonic acid (JA) and methyl jasmonate (MeJA). Combined applications of growth regulators technology containing mixture of different PGRs may be helpful in better post-harvest handling of flowers and foliage plants in order to achieve desirable results. Exogenous application of PGRs can take the place of long days to keep short-day plants or act as a substitute for natural short days for promote flowering in various short day and long day plants.

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