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Effect of gibberellic acid and benzyl adenine on ornamental plants: A review

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Abstract
Plant growth regulators are chemicals known to control and alter the physiological functions of plants. They may be synthetic or natural. The majority of the time, plant hormones and phytohormones that plants release in extremely low concentrations are regarded as natural growth regulators. When applied to various plant parts, plant growth regulators quickly move through plant tissues and are readily absorbed by plants. Additionally, a single PGR has the power to affect a variety of plant processes, but they must be handled properly to increase their efficacy in improving various plant growth and developmental processes, plant quality parameters, yield and implementing their environmentally safe use. Plant growth regulators include Auxins, gibberellins, Cytokinin, ethylene, abscisic acid. In the present review we will discuss the effect of two major plant growth regulators i.e., gibberellic acid and benzyl adenine on various ornamental crops.

Keywords: Plant growth regulators, ornamental crops, gibberellic acid, benzyl adenine

Introduction

Ornamental plants are highly valued in the global horticultural sector. Cut foliage, cut flowers, potted plants, bulbous plants, indoor plants, outdoor plants, which may be annuals, biennials or perennials in their growth habits are all examples of ornamental plants. These plants add aesthetic feelings to our environment. According to World Ornamental Plants Production (AIPH Statistical Yearbook, 2020) the total production value of ornamentals were 35.500 million euros. Plant growth regulators are a wide variety of organic compounds that can be produced either synthetically or naturally and are employed as a potential resource in the modern ornamental production system. As a cultural technique, exogenous PGR treatments help to improve the different economically valuable and marketable traits of ornamental plants. Commercial growers most frequently use synthetic plant growth regulators as they are reliable and easily accessible in the market (Patil, 2000) [1]. They are using PGRs as a cultural practice to control the plant growth and characters to suit the market needs and to match with the everchanging trend, which helps to increase the economic worth of the plant (Yawale *et al.*, 1998) [2]. PGRs are employed to affect a variety of growth and developmental processes, including initiation of rooting in cuttings, propagation techniques, flower regulation, breaking dormancy, elongation-enlargement, controlling plant structure and many more. They are being used frequently to increase crop quality and output. Depending on the dose and composition utilized, these chemicals exhibit varying reactions in various crops. Plant growth regulators have improved plant growth and production (Hernandez, 1997) [3]. The impact of PGRs depends on a number of factors that are crucial to achieving the desired results. These factors include plant species, application method, timing and number of applications, concentration of plant growth regulators and environmental conditions where the plant is grown. In order to produce compact plants with a greater number of blooms and to speed or delay flowering in accordance with the needs of the grower, the growth and flowering reactions of ornamentals plants to these chemicals have been thoroughly investigated. Gibberellic acid is one of the main plant growth regulators that has been utilized by many ornamental plant growers today. In 1926, Japanese researcher Eiichi Kurosawa made the discovery of gibberellin while looking into the bakanae or "foolish seedling" disease of rice which was caused by a fungus known as *Gibberella fujikuroi*. Later, Yabuta and Sumuki isolated gibberellin from fungal cultural extracts and named it Gibberellin. There are many forms of gibberellins present today but not all forms are biologically active. The commercially available gibberellins are GA_3, GA_4 and GA_7. Kohl and Kofranek (1957) [4] are believed to have used gibberellic acid on floriculture crops for the first time.

It encourages stem elongation, germination, root growth, breaking dormancy of buds, corms, bolting & flowering, synthesis of amylase enzyme and fruit setting (hibiscus, pansy, petunia, phlox, cineraria and many more). Another significant class of plant growth regulators is the cytokinin family also known as cell division hormone, which controls a range of processes including induction of cell division, cell enlargement, morphogenesis, delay of senescence, enhance chloroplast development and nutrient mobilization (Shudo, 1994) [5]. Kinetin was discovered by Skoog *et al.* 1965 [6]. Cytokinins are present both in natural forms and synthetic forms. Natural cytokinin are Zeatin and Coconut milk while synthetic includes Benzyl adenine (BA), Benzyl amino purine and Thidiazuron. In crops like English ivy, verbena, or stock plants where cutting output is the main goal, ornamental plant farmers may need to promote plant branching. In these cases, benzyl adenine can be employed as a branching agent. Laboratory work, turf management, the manufacturing of cut flowers, tissue culture, the cultivation of woody plants and commercial pot plant production all make use of benzyl adenines. Additionally, it has been suggested that cytokinin can replace manual pinching (Richards and Wilkinson, 1984) [7], which can help producers save money.

Effect of gibberellic acid

Gibberellic acid (GA_3) is one of the most advantageous growth regulator and has been utilized to influence different plant developmental processes, such as seed germination, increasing plant height, increasing the number of flowers, inducing flowering and sex expression and breaking dormancy (Brian, 2008) [8]. According to certain findings, GA_3 can be used effectively in the field of flower cultivation to produce high-quality blooms. Jana and Biswas (1979) [9] recorded the effects of various gibberellin concentrations on tuberose. According to their findings the plants sprayed with GA_3 @ 10 ppm at the 4-5 leaf stage produced the most leaves, spikes and flowers per plant. Banker and Mukopadhya (1982) [10] observed that when rose cultivar 'Queen Elizabeth' was treated with GA_3 at concentration 10, 25, 50, 100, 250 and 500 ppm there was significant effect on vegetative and flowering parameters of the crop. It was noticed that there was an increase in the stem length at concentration 100 and 250 ppm, increase in length of peduncle at 100 and 500 ppm, at 100 ppm there was maximum number of branches, maximum number of flowers were obtained between concentration 10-100 ppm. Thus, it was concluded that GA_3 at 100 ppm caused maximum increase in branching and high number of flowers at 10, 25, 50 and 500 ppm in rose. Dutta and Ramadas (1998) [11] carried out study to assess the effect of various plant growth regulators *viz.*, NAA (50, 75 and 100 ppm), GA_3 (50, 100 and 150 ppm), maleic hydrazide (250, 500 and 1000 ppm) and CCC (2000, 3000 and 4000 ppm) on the growth and flowering of chrysanthemum (*Dendranthema grandiflora*). The plants treated with GA_3 showed the most promising results of all the other treatments. With GA_3 at 150 ppm maximum plant height, internodal length, number of buds and lateral shoots per plant were all at their highest values. Chaudhari (2001) [12] assessed the impact of plant growth regulators on the growth, flowering and quality of the rose cultivar "Gladiator". Different concentration of GA_3 was used. The plants treated with GA_3 @ 250 ppm had maximum plant height, spread and flower production. Additionally, the maximums number of petals and longer vase life were also recorded. Dhaduk *et al.* (2007) [13] reported that the foliar treatment of GA_3 resulted in an increase in the number of flowers, stalk length, and spathe length of anthurium. Furthermore, Parmar *et al.* (2009) [14] assessed that when GA_3 was applied to spider lilies with a 15-day interval between two sprays, GA_3 @ 200 ppm demonstrated superiority over other concentrations of GA_3 (100 ppm and 150 ppm). The treatment with GA_3 200 ppm was found to be superior in all vegetative (plant height, number of leaves per plant, dry weight of plant), floral (flower diameter, spike length, number of flowers per spike, days taken for first flower emergence, days taken for first spike emergence, fresh and dry flower weight) and yield characters. Shinde *et al.* (2010) [15] observed a significant increase in plant spread, branch count, flower count, high suckers per plant and yield of flower per plant of *Chrysanthemum morifolium* cv. IIHR-6 when sprayed with GA_3 @ 200 ppm. While GA_3 at 150 ppm concentration demonstrated the earliest days for flower initiation, longest floral duration, and largest inflorescence diameter with the longest shelf and vase life. Kanwar *et al.* (2013) [16] observed that African marigold plants displayed increased plant height (83.30 cm), maximum number of flowers per plant (78.5), maximum leaf area (1188.58 cm^2), flower diameter and higher yield of flowers per plant after a single foliar application of GA_3 at 150 ppm. Aier *et al.* (2015) [17] studied the effects of various GA_3 concentrations (50, 100, 150, 200, and 150 ppm) on the vegetative and floral characteristics of the gladiolus cv. "Red Candyman". The results revealed that GA_3 at a concentration of 200 ppm showed the greatest plant height, leaf area, highest number of leaves per plant, and shortest days for flower emergence. Palie *et al.* (2016) [18] investigated how different plant growth regulators affected the development, flowering, and yield characteristics of African marigold. They reported that GA_3 @ 100 ppm increased plant height, number of branches per plant, number of leaves per plant, early flower bud initiation, first flower opening, weight of flower per plant and number of flowers per plant as compared to all other PGRs. Sumalatha (2017) [19] carried out study to assess how gibberellic acid affected the vegetative, floral, and bulb characteristics of the cv. "Menorca" of Asiatic lilium (*Lilium longifolium*). Thirty days after planting, the plants were sprayed with four different doses of GA_3 (50, 100, 150, and 200 ppm). In comparison to other treatments, GA_3 @ 100 ppm showed the most promising results. Plant height, flower buds per plant, spike length, bulb weight, bulblet weight, and bulblet number were all considerably higher than the control. Holkar *et al.* (2018) [20] investigated the influence of BA and GA_3 on gladiolus cv. "Summer Shine's". Different concentrations of BA (100, 200, and 300 ppm) and GA_3 (150, 200, and 250 ppm) were utilized separately. The findings revealed that gibberellic acid had minimum spike initiation days, first floret opening days, 50% flowering days, maximum spike girth, floret diameter and floret length at a concentration of 150 ppm. In contrast, GA_3 at 250 ppm demonstrated maximum flowering time, spike length, more florets per spike, and vase life. Alshakhaly and Qrunfleh (2019) [21] observed that *Cyclamen persicum* flowers grow more quickly when GA_3 is applied at concentrations of 5, 10, 25, 50, and 100 ppm compared to controls in both the first and second years of development. They also open more flowers at once. Mishra *et al.* (2019) [22] reported that the application of GA_3 @ 250 ppm on *Amaryllis belladonna* had a substantial effect on its growth and yield characteristics. The plants treated with GA_3 @ 250 ppm had maximum plant height (45 cm), the maximum flower stalk length (44.03 cm) and minimum days for bud initiation (143.83). Jayshree *et al.* (2020) [23] carried out an investigation on the effects of various concentrations of gibberellic acid (50, 100, and 150 ppm) on the morphological behavior of Asiatic lilies. Application of GA_3 at 200 ppm resulted in maximum plant height of 83.13 cm, maximum leaf number 67.25, leaf length of 10.27 cm, 2.52 cm in breadth, and early sprouting (6.00 days). Patel *et al.* (2020) [24] assessed the effects of foliar application plant growth regulators on the growth and flowering of potted hibiscus plants. The vegetative growth, flowering characteristics and plant pigments of *Hibiscus rosa-sinensis* plants were significantly influenced by the application of gibberellic acid, benzyl adenine and salicylic acid at different concentrations (control). Plants treated with 100 ppm gibberellic acid at 30, 60 and 90 days reached their maximum height, spread, shoot length, and leaf area. Additionally, more flowers per plant, flowers per branch, blooms with greater diameter and longer vase lives were recorded. The plants had an increase in their leaf chlorophyll content (19.50, 20.37, and 20.85 mg/g) and flower anthocyanin content (17.03, 18.65, and 20.20 mg/g) respectively at 30, 60 and 90 days after spraying. Srestha *et al.* (2020) [25] reported that different concentrations of GA_3 had a considerable effect on calendula's ability to produce high-quality flowers. They observed early commencement of the first bud and flowering with the application of GA_3 at 200 ppm to the leaves. The largest bloom width and flower weight were recorded with GA_3 @ 250 ppm, though. They came to the conclusion that a concentration of 200–250 ppm of GA_3 was the most beneficial for improving the floral quality of calendula. Yogendra (2021) [26] carried out a study to determine the effects of several PGRs (GA_3 @ 200 ppm, 300 ppm, and 400 ppm; MH @ 250 ppm, 500 ppm, and 750 ppm; and CCC @ 250 ppm, 500 ppm, and 750 ppm) on *Calendula officinalis* cv. "Bon Bon Yellow." According to the findings, the use of GA_3 greatly improved plant spread, branch and leaf counts, flower counts, early flowering, and seed production. Additionally, GA_3 was discovered to be more efficient at accelerating blooming for commercial use.

Effect of benzyl adenine

Treder *et al*. (1989) [27] assessed the influence of BA on the growth of miniature roses in pots. Benzyl adenine was applied in single and double-spraying combinations with manual pinching exercise at concentrations of 50,100, 200, and 400 ppm. The results revealed that foliar applications of BA at 50, 100 and 200 ppm on pinched plants increased the number of shoots and improved branching as compared to unpinched plants. Blanchard and Runkle (2008) carried out an investigation to determine how cytokinin affected orchid flowering (*Doritaenopsis* and *Phalaenopsis*). In this foliar application of different concentrations of BA (@ 100, 200, or 400 mg/ l) and GA_{4+7} +BA (25, 50, or 100 mg/l) were done on a weekly basis. As compared to untreated plants, the results showed that BA @ 200 ppm had the most flowers (3–8 more blooms per plant). Eid *et al.* (2010) [28] reported that foliar application of benzyl adenine dramatically boosted all flowering characteristics, the fresh weight of the bulb and bulblets per plant in *Polianthus tuberosa*. Additionally, they stated that there was a noticeable rise in floral features when the concentration was raised from 50 ppm to 150 ppm. Bhatt and Chauhan (2012) [29] studied the effect of growth regulators *viz.* GA_3 (@ 5, 10 and 15 ppm) and BA (@ 5, 10 and 15 ppm) on Dendrobium cv. 'Sonia-17,' they reported that BA @ 15 ppm significantly increased the number of leaves per plant. Additionally, BA's impact on the induction of inflorescence production in Dendrobium cv. 'Angel White' was investigated by Nambier *et al*. (2012) [30]. The results revealed that BA increased the proportion of inflorescence production and altered the length, number and generation of flowers per inflorescence. Carey *et al.* (2013) [31] carried out a study to assess the effects of various benzyl adenine concentrations on *Salvia nemorosa* L. cv. "Caradonna". They observed that foliar application of BA @ 100 to 1600 ppm (28 DAP) greatly promoted branching and flowering. BA @ 400 ppm delayed flowering by 2-3 weeks, however the plant's compactness was higher due to the abundance of flower inflorescence. According to Attiya *et al.* (2015) [32], spraying benzyl adenine at 50 ppm on lily plants considerably lengthens the time it takes for flowering in comparison to the control where no PGRs was applied. Vasudevan and Kannan (2015) [33] assessed that rose plants treated with BA at 200 ppm concentration had improved shoot length and diameter, plant spread and the number of cut stems per square meter. Also, the flower's vase life improved. Mondal and Sarkar (2017) [34] examined how benzyl adenine affected the development, flowering, yield and quality parameters of hybrid tea rose cultivar "Bugatti." It was recorded that plants treated with BA at 100 ppm had maximum spread, floral diameter (at cup stage) and maximum number of flowers per plant. BA at 200 ppm produced the most secondary shoots, stalk diameter, leaf area, and longer flower duration. They therefore came to the conclusion that BA @ 200 ppm produced the highest-quality blooms when compared to other treatments. Bala and Singh (2018) [35] observed the effect of foliar application of various PGRs on chrysanthemum. The results indicated that BA @ 200 ppm recorded the largest floral diameter (5.75 cm) and increased flower life up to 24.78 days, followed by BA @ 150 ppm. Kapri *et al*. (2018) [36] investigated the effects of GA_3 and BA on flowering and post-harvest characteristics of lily. The plants were exposed to various GA_3 and BA concentrations (100 ppm, 150 ppm and 200 ppm). The outcomes showed that a single dose of BA @ 100 ppm recorded maximum diameter, minimum days to buds color appearance and maximum vase life. While GA_3 @ 200 ppm showed early blooming. Sijo *et al.* (2020) [37] assessed how GA_3 and BA affected the morphological and floral traits of roses. The foliar application of GA_3 (at 200 ppm and 250 ppm) and BA treatments (200 ppm and 250 ppm) were done. The plants where foliar treatment of BA @ 200 ppm was done showed the maximum leaves per branch, spread of the plant and number of branches per plant. Jayshree *et al*. (2020) [38] carried out an experiment to study the effects of benzyl adenine and gibberellic acid on the morphological behavior of Asiatic lilies. In this study, a total of 16 treatments were administered with varying amounts of gibberellic acid (100, 150, and 200 ppm) and BA (50, 100, and 150 ppm). The investigation confirmed that the plants treated with BA @ 150 ppm took the longest (12.12 days) to sprout bulbs, had the largest basal stem diameter (18.06), the highest level of total chlorophyll, and the shortest plant height (36.72 cm), leaf length (7.11 cm), and leaf number (29.33).

Conclusion

Plant growth regulators are beneficial production tools that can raise product quality and marketability while lowering the work required for pinching and pruning. The use of gibberellic acid and benzyl adenine on ornamental plants has significantly enhanced their vegetative and flowering characteristics. They have had their effect in improving the physiology of plants in accordance with the market trend and grower's demand. Both, GA_3 and BA have participated in influencing the morphology of plant, flower induction process, sex expression, breaking dormancy, synthesis of proteins, cell elongation and enlargement. They must be used properly while taking into account other cultural customs, including appropriate fertility and irrigation management. Although the use of plant growth regulators in the contemporary system of ornamental production is encouraged and useful in changing a variety of growth characteristics, their improper usage can endanger the environment and can have an impact on consumer acceptability. The development of environmentally safe formulations of PGRs and their application in optimal dosage will increase their acceptability among growers and consumers.

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