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Impact of growth retardants on growth and floral characters in ornamentals: An review

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Abstract
Growth regulator is an organic compounds other than nutrients, which when used in minute quantities can either inhibit, stimulate, or alter growth. Plant growth retardants are synthetic compounds used to retard the shoot length of plants in a desired way without changing developmental patterns or evoke phytotoxic effects. This has been achieved not only by reducing cell elongation but also by lowering the rate of cell division and regulating the plant height physiologically (Rademacher, 2000). Most plant growth retardants inhibit the formation of growth-active gibberellins (GAs) and can thus be used to reduce unwanted shoot elongation (Singh, 2004). Plant growth retardant may also increase the number of lateral shoots, resulting in a larger number of inflorescences (Whealy *et al*. 1988).

Keywords: Growth retardants, growth regulator, lateral shoots, inflorescence

Introduction
The Plant growth retardants in ornamental horticulture are utilized commercially to produce compact, sturdy potted and bedding plants. This practice reduces the cost for pruning and allows obtaining a better ratio between vegetative growth and flower production, besides reducing the space in the greenhouse required for flower production and thereby improving market quality (Bekheta *et al*. 2008) [4]. Growth retardants are also used to enhance the green color of the foliage, strengthen the flower stems, stimulate flowering and promote resistance against environmental stresses (Kahar, 2008) [15]. They have also been noticed to increase the stress tolerance of plants during shipping, handling and retail marketing thereby improving the shelf life, aesthetic impression of the final product, an important aspect in marketing practices (Latimer, 2001) [20]. As chrysanthemum is considered a long day for vegetative and short day for flowering, plant growth substances are found to counter the photoperiodic requirements of pot mums and maximize flower production as per market demands (Kazaz *et al*. 2010) [16]

Effect of Growth Retardants on Growth and Flowering
Ozgur (2011) [23] reported that the seeds soaked for 24 hours in paclobutrazol of 500 and 1000 mg/l solution reduced seedling height (63.4% to 74.9%) and epicotyl diameters, leaf area, leaf and stem dry weight of Cucumber compared to control. Nazarudin (2012) [23] reported that soil drenching of paclobutrazol (0.25 g/l) significantly reduced the plant height (15.6%) and leaf area (59.6%) in *Hibiscus rosa-sinensis*. Chlorophyll content was significantly higher in PBZ-treated plants (30.6%) made the leaves appear greener. Currey and Erwin (2012) [36] reported that drench application of paclobutazol (10-40 ppm) on 11 *Kalanchoe* species (applied 2 weeks after pinching) inhibited stem elongation by 2.0 cm (17% less) most effectively in all species compared with untreated plants which is attributed to PGR solution being applied to substrate surface and subsequent root uptake. In *Kalanchoe pumila*stem suppession was 2.5 cm (39%) and in *Kalanchoe streptantha* was 2.0 cm (24%) in treated plants. Dorajeerao (2012) [6] reported paclobutrazol foliar application at 80 ppm (65 DAT) concentations in kharif and rabi seasons recorded significant reduction in plant height (85.15 cm) and leaf area (735.5 cm2) in garland Chrysanthemum (*Chrysanthemum coronarium*).Total dry matter accumulation (15.08 g/plant) and number of branches was significantly increased compared to control. Christiana da Silva *et al.* (2014) [11] reported that paclobutrazol applied at 5 and 20 mg/l in *Arundina graminifolia* was effective in controlling plant height (33 cm). Higher concentrations (10 and 20 mg/l) proved to be toxic to the plants

Effect of Paclobutrazol on flowering

Starman and Williams (2000) [30] reported that the paclobutrazol drench at 4 – 8 mg/l and of *Scaevola aemula* reduced flower stem number and length. There is no reduction in number of flowers per stem which gave floriferous, compact round clusters of the flowers. Foliar sprays at 40 and 80 mg/l did not affect most of the flowering variables. Banon *et al.* (2003) [2] reported that application of paclobutrazol 0.2, 0.3 and 0.4 mg/pot and as a single soil drench (25 DAT) in *Reichardia tingitana* reduced the number of flower buds (16.8 to 21.6 buds per plant). Doses 0.4 mg increased time taken to flowering. Flower size was not affected to any significant degree. The number of flower stems per plant and flower stem diameter (52.1%) was highly and significantly decreased. Haque *et al*. (2007) [13] reported that paclobutrazol application at 80 and 160 mg/l increased pyrethrins level (21%), single flower weight and decreased flower yield in *Chrysanthemum cinerariaefolium*. Dorajeerao (2012) [6] reported paclobutrazol foliar application at 40,60 and 80 ppm concentrations in kharif, rabi seasons recorded a higher number of flowers per plant than control in garland Chrysanthemum (*Chrysanthemum coronarium*). Increase in concentrations, reduced the number of flowers per plant.There was an increase in the flower yield per plant by the foliar application than untreated plants. Nazrudin (2012) [23] reported that soil drenching of paclobutrazol (0.25 g/l) at 75 days after application, significantly increased number of blooms (39.5%), induced uniform flowering in *Hibiscus rosa-sinensis* and delayed flowering by 26 days. Significant positive relationship found between number of blooms and total root length. Vaghasia and Polara (2015) [31] reported that Paclobutrazol at 0.4ml/l and 0.5ml/l spray application on Chrysanthemum (*Dendranthema grandiflora*) reduced the days to first flower bud appearance, first flowering and days to 50% flowering at 30 DAT. Number of flowers per plant was increased which attributed to more number of branches accumulated more carbohydrates used to increase flower yield.

Effect of Daminozide on growth parameters

Kofidis and Ginnakoulu (2007) [19] reported that daminozide applied at 500 and 1000 mg/l resulted in 25% shorter plants of *Coriandrum sativum* than controls and reduced stem internodal length. The leaf thickness and stem diameter (17-37%) was significantly increased. Chlorophyll content of treated plants was increased by 16% resulting in dark green leaves. Essential oil and fruit yields were declined. Lorena and Carolina (2010) [22] reported that the application of daminozide twice (15 and 30 days after sowing) at 6000 mg/l, three times at 4000 mg/l decreased the final plant height (<2 meters) by reducing the unwanted longitudinal growth of Sunflower (*Helianthus Annuus*) adequate as cut flower inside the green house, but not small enough to grow it as a potted plant. Head diameter was not decreased attending the consumer preference of big Sunflower. Kazaz *et al.* (2010) [17] reported that day length (SD conditions) and daminozide (3000 mg/l) significantly reduced the stem length (79.21 cm) compared to control (89.73 cm) in *Chrysanthemum morifolium.* Stem diameter, stem fresh weight (128.12 g/stem), dry matter content (19.44%) of the plants, Chlorophyll a and b were significantly increased (11.5 µg/mg) in treated plants under LD conditions. Zakrzewski and Anita Schroeter (2011) [35] reported that the application of Metaconazole once (300 mg/ dm^3) and daminozide applied twice of 2,550 mg/dm^3 in autumn growing period reduced the height (7.0 cm) as well as number of shoots (6.2) of *Chrysanthemum grandiflorum* compared to control (22.6 cm and 8.3 numbers respectively). Plant width was decreased in spring and summer terms. Ahmad Bhat *et al.* (2011) [1] studied effect of foliar spray of cycocel and B-9 on *Erysimum marshalii* and reported that plant height was not affected by B-9 at 500,1000 and 1500 mg/l application. Number of laterals was slightly decreased and leaf area was significantly decreased by B-9 application. The fresh and dry mass of leaves, roots and stem was decreased. Kazemi *et al.* (2014) [18] reported that application of daminozide at 3000 mg/l and 4500 mg/l limited the stem elongation and reduced the plant height (24 cm) of Marigold (*Calendula Officinalis*) 5-6 weeks after potting. Plant fresh weight, dry matter, essential oil and chlorophyll content were significantly increased. Largest number of leaf was obtained in 3000 mg/l application. Ganesh (2014) [9] reported that single application of daminozide at 1500 and 2500 ppm at (7 and 14 days after darkening) reduced the plant height (34.33 cm.) of *Chrysanthemum* Var. Punch at considerable level. Leaf area, cut steam girth (3.24 cm), steam fresh weight (68 gm) and chlorophyll content, cut stem yield (77.34 stems/m^2) and pedicel length (5.87 cm), soluble protein content (80.66mg/g) were increased.

Effect of Daminozide on flowering

Christiana *et al.* (2014) [1] reported that spray application of daminozide (2.5 and 3.75 g/l) in *Zinnia elegans* promoted flowering and increased inflorescence dry mass, reduced inflorescence diameter with 5.0 g/l application. There were no apparent effects on inflorescence color and shape. Inflorescence harvest index was increased (0.22 g) with increasing concentrations. Daminozide promoted the translocation of photosynthates to the inflorescences thus improved plant quality and delayed flowering time which is attributed to restriction in gibberellins. Kazaz *et al.* (2010) [17] reported that day length (SD conditions) and daminozide (3000 mg/l) significantly had a higher number of flowers per stem (14.11 flowers / stem) in *Chrysanthemum morifolium* whereas 11.17 flowers per stem in untreated plants. Days to flower were slightly delayed (0.58 days) and there was increase of yield and compact, uniform quality of flowers with both under SD conditions and the treatment application. Zakrzewski and Anita Schroeter (2011) [35] reported that the application of Metaconazole once (300 mg dm3) and daminozide applied twice of 2,550 mg/dm3 in summer growing period of *Chrysanthemum grandiflorum* produced greatest number of flower heads (20 flower heads). Flowering was delayed between 3 to 8 days in treated cultivars 'Paloma' and 'Hellen'. In autumn treated plants produced smaller number of inflorescences and reduction in flower head diameter. Ahmad Bhat *et al.* (2011) [1] studied the effect of foliar spray of cycocel and B-9 on *Erysimum marshalii* and reported that B-9 at 500, 1000 and 1500 mg/l application slightly decreased the flowering yield and flower diameter compared to controls. The number of flowers was decreased and number of floral heads was increased than control. Davood *et al*. (2012) [12] reported that number of flowers was strongly influenced by interaction effect of CCC and B-9 in *Calendula officinalis.* Application of B-9 1500 mg/l + CCC 500 mg/l produced the highest number of flowers per plant (3.33) that is 150% more than that of control. Highest amount

of essential oils per 100 g dried flower (0.159 ml) was observed with application of B-9 at 4500 mg/l and flower quality was increased in treated plants than control. Flower fresh weight was increased in line with increasing concentrations. Days to flowering were delayed under all concentrations. Kazemi *et al.* (2014) [18] reported that application of daminozide at 1500 mg/l and 4500 mg/l resulted in maximum number (4.66/plant) of flowers than control in Pot Marigold (*Calendula Officinalis*). Petal essential oil (0.15 ml/100 g FW), carotenoid (8.22 mg/l) content was increased. Lowest time of flowering (98.00) days were related to 1500 ppm application when compared to control (122.60 days). Ganesh (2014) [9] reported that single spray application of daminozide at 2500 ppm in *Chrysanthemum* Var. Punch significantly increased the number of flowers per spray. Number of days to flowering (44.72) and days to harvest (81.33 days) was reduced compared to control. There was marketable reduction (67.07 and 79.07 cm) in flower stalk length.

Effect of Daminozide on vase life

Kahar (2008) [16] reported that the increased concentration from 0 to 5000 mg/l of daminozide in *Chrysanthemum* 'Regan Sunny' doubled the vase life with one application, but the reverse response was found with two and three applications. Single application with the concentrations of 1,250 and 2,500 mg L-1 is recommended for production of good spray form and long vase life for chrysanthemum. Patil (2013) reported that the application of daminozide at 1500 ppm enhanced the vase life by 2.60 days in China aster (*Callistphus chinensis*) compared to untreated (control) plants which is attributed to increased chlorophyll content of leaves and ultimately resulting in increase in vase life of flowers in both varieties Phule Ganesh White and Phule Ganesh Violet. Ganesh (2014) [9] reported that single spray application of daminozide at 2500 ppm *Chrysanthemum* var. Punch significantly increased vase life (12.50 days) at 7 days after darkening than control (5.27 days) which is attributed to internal physiological status of the cut stems delaying early onset of the senescence.

Effect of Ethephon on growth parameters

Banon *et al.* (2001) [3] reported that application of ethephon 0.5 to 5 g / plant in *Nerium oleander* inhibited plant growth (15 to 48%). Number of branches significantly increased from 1.8 to 3.8. Internodal length (12 and 50.8%) and leaf blade area (46 to 71%), dry weight of aerial part (15 to 58%) were reduced significantly compared with control. Only 5 g dose reduced chlorophyll content. Chen *et al.* (2002) [10] reported that ethephon treated plants at 250 and 500, 1000 ppm produced significantly more lateral shoots resulting in compact plants in *Gynura aurantiaca* with shorter stems and internode lengths without reduction in leaf sizes compared to control. Banon *et al.* (2003) [2] reported that the application of ethephon 100 mg/plant significantly reduced plant height by 50.3% in *Reichardia tingitana.* Plant width and aerial part dry weight (87.1%), leaf blade area (88.6%) were reduced. Relative chlorophyll content (36.4%) was reduced. Krug *et al.* (2006) [20] reported that foliar spray of ethephon at 500 to 2500 mg/ l controlled stem stretch during postharvest evaluation in *Narcissus pseudonarcissus* resulting in 19% shorter plants (25.7 cm tall) than control. Plant height of 'Tete a Tete' narcissus during greenhouse forcing was not controlled at any concentrations used. Foliar sprays of 1000 to 2000 mg/l recommended to maintain a marketable plant height. Helen *et al.* (2007) [15] reported that application of ethephon spray at 500 and 1000 mg/l twice (applied 1 week after the initial treatment) resulted in 15-25% more compact plants than untreated controls of blanket flower "Torch Flame" (*Gailardia pulchella*). Dry weight of plants (34%), growth indices was significantly lowered. Increasing the rate of application increased the visual compactness. William *et al.* (2010) [34] reported that substrate drench of ethephon 250mg/l applied in *Narcissus* cultivars resulted 20% to 40% shorter plants than control by inhibiting stem elongation and the effect increased with increased concentrations (250 and 500 m/l). Among Bedding plants (*Catharanthus*) ethephon drench suppressed plant height by 30% but only 10% to 15% in *Lobelia lycopersicon, Celosia,* and *Tagetes.* Dry mass accumulation is decreased in all crops. Curry and Erwin (2012) [36] reported that spray application of ethephon (250-1000 ppm) on 11 *Kalanchoe* species (applied 2 weeks after pinching) inhibited stem elongation by 2.9 cm (37% less) in all species compared with untreated plants. Ethephon increased the number of branches for, *Kalanchoe rosei* and *Kalanchoe glaucescens* speceis by 1.6 and 3.6 branches. Phyto toxicity was observed in *Kalanchoe manginii* at 1000 ppm, the epical meristem was distorted, resulting in sutnted plants with few unfolded leaves and branches. At 20 ppm, *Kalanchoe rotundifolia* plants were very stunted.

Effect of Ethephon on flowering

Burnett *et al.* (2000) [5] reported application of ethephon 500 and 1000 ppm delayed flowering by 11 to 13 days in the first year of experiment in *Achillea*cv. 'Coronation gold 'and *Gaura lindhemeri* cv. 'Corrie's gold'. Some treated plants did not reach marketable quality with fewer and smaller flowers. In the second year of experiment flowering delay and decrease in number of flowers were not seen as flower buds were not visible during the treatment. Banon *et al.* (2003) [2] reported that the application of ethephon 50, 75 and 100 mg/plant (25 DAT) in *Reichardia tingitana* delayed the flowering. Number of flowering stems and number of inflorescences per plant were significantly reduced. Flower size, internodal distance and number of flowering buds were substantially reduced. Haque *et al.* (2007) [14] reported that ethereal applied at 50,100,250 and 500 mg/l in *Chrysanthemum cinerarifolium* produced positive effect on pyrethrins level by 20 and 26% in pyrethrin-1 and by 31 and 44% in pyrethrin-2 and significantly increased fresh and dry flower yield (38 to 42%) as compared to untreated plants. Flower yield decreased by higher doses of etherel (250 to 500 mg/l) but single flower weight was not affected significantly. Helen *et al.* (2007) [15] reported that application of ethephon spray at 500 and 1000 mg/l resulted in delay of flowering in blanket flower "Torch Flame" (*Gailardia pulchella*) regardless of application rate or number. Pedicel elongation was reduced in treated plants compared to control. Number of flowers was not affected by a second spray (at 3 weeks) of application.

Effect of Ethephon on vase life

Finger and Campanha (1999) [7] reported that the application of ethephon at 10 and 100, 1000 mg/l in Bird of paradise (*Strelitzia reginae*) had little influence on flower longevity (vase life) which is attributed to the apparent lack of

sensitivity to ethylene of this flower, even though it is known that ethylene causes senescence and wilting of petals and tepals in many flower species. Van Droon *et al.* (2011) reported that the application of ethephon limited the vase life of Cut Tulips (*Tulipa* spp.) by a combination of leaf yellowing, tepal senescence, and tepal abscission. Stem bending which is resulted by high rate of stem elongation could be prevented by treatment with ethylene or ethephon. However, these treatments resulted in poor flower opening. The ethephon treatment also resulted in precocious tepal abscission. The negative effect of ethephon on flower opening was overcome by a treatment with gibberellic acid.

Effect of Uniconazole on growth parameters

Warner and Erwin (2003) [32] reported that one-time spray application of uniconazole (5 and 10 mg/l) reduced stem elongation of *Hibiscus radiatus* by 19% (28 days after application) but did not impact stem elongation I n*Hibiscus trionum* compared to untreated plants. Therefore, multiple applications or higher doses may be necessary for adequate control. Application in *Hibiscus rosa- sinensis* resulted inreduced plant height by 75% and darker green colour in leaves. Helen *et al*. (2007) [15] reported that drench application of Uniconazole at 6 and 12 mg/l and spray application at 60 and 120 mg/l resulted in reduced growth indices (12% to 30%) and dry weights (16 to 31%) in blanket flower (*Gailardia pulchella*), with greater compactness than control plants. Increasing the rate of application linearly decreased the parameters. Drench application was more effective compared to spay application of uniconazole which is attributed to the greater chemical uptake by roots and transportation through xylem. Gaber (2009) [8] reported that application of uniconazole drench or spray in six concentrations (0.20.30,40,50 and 60 ppm) reduced the plant height in *Mirabilis jalapa* compared to control and significantly retarded the internodal length. Leaf area was less with 50 and 60 ppm. Shoot dry weight was decreased with 20 to 60 ppm foliar spray. Number of internodes and leaf carotenoids and chlorophyll content were increased. There was reduction in sugar content during both seasons of the experiment. Currey (2010) reported that application of uniconazole at 1.0 to 2.0 ppm suppressed final stem length (3.7 to 5.2 cm. shorter) of Calibrachoa (*Calibrachoa***hybrid*) and plant height (10.0 to 11.3 cm. shorter) of Pansy (*Viola wittrockiana*) after planting in containers filled with substrate containing 80% peat and 20% parboiled Rice Hulls. Based on these results it is concluded that Rice Hulls did not reduce PGR drench efficacy on plants. Nazarudin (2012) [23] reported that uniconazole spray applications at 2 mg/l significantly reduced the plant height (15.6%) and leaf area (59.6%) in *Hibiscus rosa-sinensis*. Chlorophyll content was significantly higher in treated plants (30.6%) made the leaves appear greener. Increased root length (38.1%) was found in treated plants than control. Currey and Erwin (2012) [36] reported that foliar spray of uniconazole (5 – 20 ppm) on 11 *Kalanchoe* species (applied 2 weeks after pinching) inhibited stem elongation by 4.9 cm (63% less) in all species compared with untreated plants. Stem elongation inhibited by 4.2 cm (44%) in *kalanchoe fedtschenkoi* and in*kalancoe pumila* by 3.0 cm (47%).The highest suppression was 7.2 cm (85% less) in *Kalanchoe spectrantha* and severe stunting was observed with 20 ppm application in *kalanchoe glaucescens.*

Effect of Uniconazole on flowering

Starman and Williams (2000) [28] reported that the uniconazole drench 1–2 mg/ l, in *Scaevola aemula* decreased flower stem number and length significantly. Flower stem number per cm is increased in all cultivars resulting in floriferous appearance. There was no delay in flowering of treated plants. Spray application did not affect most of the flowering variables. Gaber (2009) [8] reported that application of uniconazole drench or spray in six concentrations (0.20.30, 40, 50 and 60 ppm) significantly decreased the number of flowers per plant at 30 and 40 ppm spays in first year and at 20 and 60 ppm sprays in second year. Flowering was delayed significantly in both seasons. Nazarudin (2012) [23] reported that uniconazole spray applications at 2 mg/l significantly increased number of flower buds at 10 weeks after treatment but delayed blooming in *Hibiscus rosa-sinensis.* Uniconazole was found to be more effective in promoting flowers compared to control and therefore recommended for flower induction at 2 mg/l in potted *Hibiscus*. A significant positive relation was found between number of blooms and total root length.

Effect of Uniconazole on vase life

Hamada *et al*. (1989) [13] reported that the application of 20 mg/l uniconazole treatment was extended vase life of cut flowers in Tree peony but in herbaceous peony, treatment did not extend vase life of cut flowers. The application delayed opening of petals in cultivar 'Taiyoh'. Stamps (1990) [29] reported that the foliar spray application of uniconazole at 25 and 100 ppm in Vibranum Stems (*Vibrunum adoratissimum*) and Variegated Chinese privet (*Ligustrum indica*) reduced the vase life by 7.7 and 7.2 days respectively when compared to control plants.

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