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APPLICATION OF PLANT GROWTH REGULATORS IN ORNAMENTAL PLANTS: A REVIEW

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Ornamental plants hold an important status in the horticultural industry of the world. Plant growth regulators consist of a large group of naturally occurring or synthetically produced organic chemicals and considered as helping tool in the modern production system of ornamentals. Their exogenous application helps to improve the different economically important and market desirable characteristics of ornamental plants. The use of plant growth regulators is being practiced by the commercial growers of ornamental plants as a part of cultural practice. There are various factors contributing to the efficacy of plant growth regulators and the method of application plays key role in determining the effectiveness of plant growth regulators, as PGRs can be effective if properly absorbed by plants. There are various methods of application of PGRs but the most popular are foliar sprays, drenching and pre-plant soaking while the efficacy of each method depends on the various factors including the mode of absorption of PGRs by different plant parts, method of application and environmental factors. Further development to focus the variables that can affect the response of plant to plant growth regulators will help to increase the efficiency of PGRs and avoid phytotoxicity which can maximize their productivity.
Keywords: Phytohormones, ornamental horticulture, plant production, growth regulation, application methods

INTRODUCTION

Economic importance of ornamental plants: Ornamental plants represent a great diversity of beautiful plants, including cut foliage, cut flowers, bedding plants, indoor plants, potted plants, bulbous plants, outdoor plants, which may be annuals, biennials or perennials in their growth habit. Thus ornamentals bring aesthetic feelings to our surroundings (Riaz *et al*., 2002; Memon *et al*., 2013) and also economically important in horticultural trade, all over the world. They are also being used by the humans, even in the prehistoric times (Simpson and Ogorzaly, 2001) and the demand of ornamental plants for personal and ceremonial use has been increased. Cut flowers dominate among ornamental plants followed by flowering pot plants, tree and nursery plants, and flower bulbs (Lawson, 1996) but now the trend has been changed. The rapid rise is seen in the production of horticultural crops, including the ornamental plants (Janick, 2007), and covered the 42% of the total cash received from horticulture farms and 6% of all agriculture farms in Canada (AAFC, 2005). The total export of floriculture is increased by 1.9%, while 5.3% increase in case of cut flowers in 2011 (MNS, 2012). The ornamental plants (flowering and potted) having value of 32 billion euro were produced in the world in 2014 and Europe contributed 34.3% followed by China (15.9%) (AIPH, 2015). Area under production of flower and ornamental plants in Europe is 74 thousand hectare and Netherland is leading by sharing 35% of total area in 2013 (EUROSTAT, 2015).

What are plant growth regulators: Plant growth regulators (PGRs) consist of organic molecules, produced synthetically and used to alter the growth of plants or plant parts. They have ability to accelerate or retard the plant growth. The hormone which is produced in plants is called as plant hormone and also known as phytohormone. Phytohormone is defined as, an organic substance produced naturally in higher plants, controlling growth or other physiological functions at a site remote from its place of production, and active in minute amounts (Thimann, 1948). PGRs sometimes confused with plant hormones, but there are certain differences among them as the term PGRs is used by agrochemical industry to indicate synthetic plant growth regulators, while plant hormones are a group of naturally occurring, organic substances which influence physiological processes at low concentrations (Davies, 2010). The growth hormone is the phytohormone and is essential to growth of organs as buds, stems, roots, fruits, and so on by cellular enlargement, both in length and in width, while growth regulator referred to organic compounds other than nutrients, small amounts of which are capable of modifying growth (Leopold, 1955). The PGRs can be biostimulant or bioinhibitor and are active even at very low concentrations in plant cells and have ability to alter the growth and development. The plant growth regulators represent various categories as American Society for Horticultural Science also divides the plant growth regulators into six classes including gibberellins, auxins, cytokinins, ethylene generators, growth inhibitors and growth retardants. There are certain other groups which are considered as PGRs including polyamines, as they have an important role in plants and are also categorized as a new class of plant growth bio regulators due to their promotive effect on plant growth (Mahgoub *et al*., 2006, 2011) and vitamins which are also considered as growth bio-regulators as their low concentration may exert a great influence on factors that affect metabolic pathways, plant growth regulation and physiological processes including synthesis of enzymes and co-enzymes (Hathout, 1995; Robinson, 1973). There are various commercial available formulations of synthetic growth regulators being used on ornamental plants (Table 1).

***Factors affecting efficiency of PGRs*:** The effects of PGRs in plants depend on various factors which play important role to achieve expected results. These factors include the application method, time of application, concentration of PGRs, plant species and also the environmental conditions in which plants are grown (Grzesik, 1989; Wroblewska and Dębicz, 2013). The intensity of applications is also considered an important factor affecting the efficacy of PGRs, as some plants respond well to a single application, but in most of cases, multiple applications are beneficial to attain good results (Carey *et al.,* 2007). The other supplementary factors may include the chemical properties of PGRs solution, particularly the pH, which plays a key role in the absorption of PGRs by the plants. We discuss the application methods and their possible advantages over one another.

***Application methods*:** There are various methods of application of PGRs in plants reported in literature, mostly including foliar application (Sajjad *et al*., 2014), drenching (Matsumoto, 2006), pre-plant sowing (Currey and Lopez, 2010), seed priming (Pill and Gunter, 2001), pasting (Saniewski *et al*., 2010), capillary string (Carswell *et al*., 1996) and injection (de Vries and Dubois, 1988). The most commercially adopted methods for ornamental plants are foliar spray, drenching and pre-plant soaking (includes dips for shorter period of time) as shown in Table 2. The research in methods of application of PGRs reported that their early application such as dipping before planting and substrate drenching at planting time are helpful in obtaining desired results and also supportive in the efficient use of these chemicals (Magnitskiy *et al*., 2006; Ranwala *et al*., 2005).

The possible effects of PGRs depend on their method of application due to the difference in their mode of absorption by the plant, as some chemicals are absorbed only through root, leaves or stem, and some are absorbed through all mentioned organs having an advantage to apply in either way, as ancymidol is absorbed by the roots, stem and also leaves (Whipker *et al*., 2003b) while B-Nine is only absorbed through foliar sprays but Bonzi and sumagic are absorbed through the stem and root zone (Latimer, 2009).

Foliar application and soil drenching are the most common methods being used by commercial growers (Lee and Rho, 2000) and relatively higher concentrations of PGRs are used

Table 1. Commercially available synthetic growth regulators for ornamental plants.

Plant Name	Active Compounds	Trade Names	Main Effects	Reference
Ageratum	Ancymidol	A-Rest, Abide	Control plant growth	Bailey and Whipker, 1998; Whipker, 2013
Aster	Daminozide	B-Nine, Compress, Dzide	Control plant growth	Bailey and Whipker, 1998; Whipker, 2013
Begonia	Ethephon	Florel	Enhance lateral branching, as pinching agent	Bailey and Whipker, 1998; Whipker, 2013
Dhalia	Uniconazole	Sumagic, Concise	Control plant growth	Bailey and Whipker, 1998; Whipker, 2013
Easter	6-benzyladenine and gibberellins A4 + A7	Fascination, Fresco	Prevent yellowing of leaves	Latimer, 2009
Fagus	Indole Butyric Acid	Chryzopon, C-mone, Rhizopon	Promote rooting	Percival and Barnes, 2004
Gomphrena	Chlormequat chloride	Citadel, Cycocel	Control plant growth	Bailey and Whipker, 1998; Whipker, 2013
Impatiens	Paclobutrazol	Bonzi, Downsize, Paczol, Piccolo	Control plant growth	Bailey and Whipker, 1998; Whipker, 2013
Kalanchoe	Dikegulac sodium	Atrimmec, Augeo	Enhance lateral branching	Bailey and Whipker, 1998; Whipker, 2013
Ornithogalum	Gibberellic acid	Florgib, ProGibb	Promote vegetative and flower growth	Wang and walter, 2006
Petunia	6-benzyladenine	Configure	Increase lateral branches	Carey etal ., 2007
Vinca	Flurprimidol	Topflor	Control plant growth	Whipker *et al*., 2003a

in case of foliar sprays (Al-Khassawneh *et al*., 2006). It is required to use compressed air sprayer and same nozzle for all the plants to ensure the equal volume of PGRs to plants in case of foliar sprays. The high concentration of some PGRs can cause toxicity to the plant (Ranwala *et al.,* 2002), sometimes resulted in stunted growth (Cox and Keever, 1988) and also increases the input cost. Foliar application can be more effective if applied at the right stage of growth for controlling specific characters and it requires information about the phenology of the target plant. Another advantage of foliar spray is the repetition of application as many times as required can be made to attain certain goals. The plant response to foliar application also depends on the absorption rate and absorption is driven by the environmental conditions, temperature and humidity are the most important. Slightly high temperature, high humidity and longer drying time are reported to increase the absorption of PGRs in plants (Stover and Greene, 2005).

Soil drenching is efficient method and PGRs are used in relatively lower doses but residual effects of PGRs are retained in pots which sometimes harm the plant. Drenching has advantage over foliar sprays because it ensures the uniformity of treatment as each plant receives the measured amount of PGRs and absorption occurs through root zone. This method is suitable for PGRs having efficient absorption through root medium (Sanderson *et al*., 1988). Substrate drenching requires more labor compared to other methods (Krug, 2004); hence, it may not be cost effective if the labor is heavily paid in that area.

Preplant soaking of plant material in PGRs is reported an efficient method but their use is relatively less common on commercial scale (Ranwal *et al*., 2002; Sajjad *et al*., 2015). This method has advantages of time and labor saving, accurate dosage over other methods, but disposal of residual solutions can be problematic (Larson *et al*., 1987) as some PGRs including paclobutrazole, uniconazole, ancymidole etc. cause toxicity to the surrounding environment when disposed in an open environment. This problem can be solved by applying the used solutions as a substrate drench for another time (Krug, 2004). There are certain factors which affect the effectiveness of this method, and the most important are the concentration of PGRs and duration of

Table 2. Application methods of plant growth regulators in ornamental plants.

Plant Name	Method of application	Reference
African violet	Foliar sprays	Martin-Mex *et al*., 2005
Allium moly	Pre plant soaking/dipping	Laskowska *et al.,* 2013
Argyranthemum frutescens	Pre plant soaking/dipping	Blanchard and Runkle, 2007
Bletilla striata	Pre plant soaking/dipping	Yoon *et al.,* 2002
Bougainvillea glabra	Foliar sprays	Moneruzzaman *et al.,* 2010
Caladium bicolor	Pre plant soaking/dipping	Whipker *et al.,* 2005
Chrysanthemum morifolium	Foliar sprays	Sugiura, 2004
Codiaeum variegatum	Foliar sprays	Eid and Abou-Leila, 2006
Dahlia pinnata	Foliar sprays	Mahgoub *et al.,* 2011
Euphorbia pulcherrima	Drenching	Lodeta *et al.,* 2010
Gladiolus grandiflorus	Foliar sprays	Sajjad *et al.,* 2014
Hemerocallis lilioasphodelus	Foliar sprays	Amling *et al.,* 2007
Hibiscus coccineus	Foliar sprays	Warner and Erwin, 2003
Hosta spp.	Foliar sprays	Witomska *et al.,* 2010
Hyacinth orientalis	Pre plant soaking/dipping	Krug *et al.,* 2006
Hylocereus undatus	Foliar sprays	Khaimov and Mizrahi, 2006
Iris germanica	Foliar sprays	Leeson and Harkess, 2006
Lilium longiflorum	Pre plant soaking/dipping	Christopher and Lopez, 2010
Miltoniopsis vexillaria	Drenching	Matsumoto, 2006
Nandina domestica	Foliar sprays	Keever and Morrison, 2003
Phalaenopsis amabilis	Foliar sprays	Blanchard and Runkle, 2008
Philodendron Schott	Foliar sprays	Chen *et al.,* 2003
Reichardia tingitana	Drenching	Banon *et al.,* 2003
Rhododendron catawbiense	Drenching	Gent, 2004
Rosa damascena	Foliar sprays	Abbas *et al.,* 2007
Salvia officinalis	Foliar sprays	Carey *et al*., 2013
Scaevola aemula	Pre plant soaking/dipping	Schnelle and Barrett, 2010
Solida gorugosa	Foliar sprays	Lieth and Dodge, 2004
Tulipa gesneriana	Pre plant soaking/dipping	Ramzan *et al*., 2014

dipping of plant material in the solution (Ranwala *et al.,* 2002). Application of PGRs in lower dose favors their use economically on large scale and use of low doses are effective if the duration of dipping is increased, as increase in duration may increase the absorption of chemical (Parivar *et al*., 1985) which can accelerate effectiveness.

***Various attributes of ornamentals improved by exogenous application of PGRs*:** The exogenous application of PGRs has been reported numerous times in various ornamental plants including gladiolus (Sajjad *et al*., 2015), tulip (Ramzan *et al*., 2014), dahlia (Mahgoub *et al*., 2011), lily (Currey and Lopez, 2010), iris (Leeson and Harkess, 2006) etc. Their application was restricted in scientific experiments initially, but later on, was started to use on commercial farms and now is being applied by the progressive growers to improve different characteristics in ornamental plants. Although, the objective of the application of PGRs differs according to the type of plant but the increase in compactness of foliage is required in certain ornamental plants and improvement in flower characteristics is also a key objective in some other ornamental plants. The PGRs has been applied to alter various characteristics in ornamental plant including the increase or reduction in plant height (Christopher and Lopez, 2010; Francescangeli *et al.*, 2007), increase compactness in plants (Meijon *et al*., 2009; Rademacher, 1991), an increase in number of flowers (Sajjad *et al*., 2014; Carey *et al*., 2013), early flowering (Cardosol *et al*., 2010; Khaimov and Mizrahi, 2006), increase in number of lateral shoots (Wroblewska and Debicz, 2013;Witomska *et al*.,2010), delay in flowering (Taha, 2012), control of sex ratio in flowers (Gayakvad *et al.,* 2014), delayed senescence (Chang *et al*., 2003; Duan *et al*., 2006), increase flower life (Khandaker *et al*., 2013; Gulzar *et al.,* 2005), induce systemic acquired resistance against diseases (Darras *et al*., 2011; Dinh *et al.,* 2007), resistance against pathogen (Pozo *et al.,* 2005; Jameson and Clarke, 2002), breaking dormancy (Gashi *et al*., 2012; Guleryuz *et al*., 2011), reduce the vernalization requirement (Wang and Walter, 2006), improve seed germination (Rehman and Park, 2000; Khan *et al*., 2004) and increase vase life (Gholami *et al*., 2011; Iqbal *et al*., 2012).

***Future challenges for PGRs and their alternatives*:** Although the use of PGRs is encouraged in the modern production system of ornamentals and also helpful in altering various growth characteristics but their unjudicial use can threaten the environment and also effect the consumer acceptability, as commercial available PGRs formulations consists of synthetic growth regulators. The synthesis of ecological safe formulation of PGRs and their usage in optimum dosage will enhance their acceptability by the growers as well as consumers. The second way is to use alternative approaches for alteration of growth characteristics in ornamentals including the genetic engineering, gene silencing, manipulation of environmental factors especially temperature, light, and water stress technique to control growth of ornamentals.

REFERENCES

AAFC. 2005. Overview of Canadian horticulture. Agriculture and Agri. Food, Canada.

Abbas, M.M., S. Ahmad and R. Anwar. 2007. Effect of growth retardants to break apical dominance in *Rosa damascena*. Pak. J. Agric. Sci. 44:524-528.

AIPH. 2015. International Association of Horticultural Producers. Available online at http://aiph.org

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

Amling, J.W., G.J. Keever, J.R.J. Kessler and D.J. Eakes. 2007. Benzyladenine (BA) promotes ramet formation in *Hemerocallis*. J. Environ. Hort. 25:9-12.

Banon, S., J. Ochoa, J.A. Fernández, A. González, J.J.M. Sánchez and J.A. Franco. 2003. Plant growth retardants for introduction of native *Reichardia tingitana*. Acta Hort. 598:271-277.

Blanchard, M.G and E.S. Runkle. 2007. Dipping bedding plant liners in paclobutrazol or uniconazole inhibits subsequent stem extension. HortTechnology 17:178-182.

Blanchard, M.G. and E.S. Runkle. 2008. Benzyladenine promotes flowering in *Doritaenopsis* and *Phalaenopsis* orchids. J. Plant Growth Regul. 27:141-150.

Cardosol, J.C., E.O. OnoII and J.D. Rodrigues. 2010. Gibberellic acid and water regime in the flowering induction of Brassocattleya and Cattleya hybrid orchids. Hortic. Bras. 28:395-398.

Carey, D.J., B.A. Fair, W. Buhler, I. McCall and B.E. Whipker. 2013. Growth control and flower promotion of salvia with benzyladenine foliar sprays. J. Appl. Hort. 15:87-89.

Carey, D.J., B.E. Whipker, I. McCall, and W. Buhler. 2007. Cytokinin based PGR affects growth of vegetative petunia, p.285. In: S.M. Reed (ed.), Growth Regulators. Proc. Southern Nursery Assoc. Res. Conference, 8-9 Aug. 2007, Atlanta, America.

Carswell, F.E., J.S. Day and K.S. Gould. 1996. Cytokinins and the regulation of plant form in three species of *Sophora*. New Zeal. J. Bot. 34:123-130.

Chang, H.C., M.L. Jones, G.M. Banowetz and D.G. Clark. 2003. Overproduction of cytokinins in petunia flowers transformed with PSAG12-IPT delays corolla senescence and decreases sensitivity to ethylene. Plant Physiol. 132:2174-2183.

Chen, J., R.J. Henny, D.B. McConnell and R.D. Caldwell. 2003. Gibberellic acid affects growth and flowering of

Philodendron 'Black Cardinal'. Plant Growth Regul. 41:1-6.

Christopher, J.C. and R.G. Lopez. 2010. Paclobutrazolpre-plant bulb dips effectively control height of 'Nellie White' Easter lily. HortTechnology 20:357-360.

Cox, D.A. and G.J. Keever. 1988. Paclobutrazol inhibits growth of zinnia and geranium. HortScience 23:1029-1030.

Currey, C.J. and R.G. Lopez. 2010. Paclobutrazol pre-plant bulb dips effectively control height of 'Nellie White' easter lily. HortTechnology 20:357-360.

Darras, A.I., D.C. Joyce and L.A. Terry. 2011. MeJA and ASM protect cut Freesia hybrid inflorescences against *Botrytis cinerea*, but do not act synergistically. J. Hort. Sci. Biotechnol. 86:74-78.

Davies, P.J. 2010. The plant hormones: their nature, occurrence, and function, pp.1-15. In: P.J. Davies (ed.), Plant Hormones: biosynthesis, signal transduction, action. Springer, Netherlands.

De Vries, D.P. and L.A.M. Dubois. 1988. The effect of BAP and IBA on sprouting and adventitious root formation of 'Amanda' rose single-node softwood cuttings. Sci. Hortic. 34:115-121.

Dinh, S.Q., D.C. Joyce, D.E. Irving and A.H. Wearing. 2007. Field applications of three different classes of known host plant defense elicitors did not suppress infection of *Geraldton waxflower* by *Botrytis cinerea*. Australas. Plant Path. 36:142-148.

Duan, H. , Y. Li, Y. Pei, W. Deng, M. Luo, Y. Xiao, Luo K., L. Lu, W. Smith, R.J. McAvoy, D. Zhao, X. Zheng and C. Thammina. 2006. Auxin, cytokinin and abscisic acid: Biosynthetic and catabolic genes and their potential applications in ornamental crops, pp.347-364. In: Y. Li and Y. Pei. (eds.), Plant Biotechnology in Ornamental Horticulture. The Haworth Press, Inc., New York.

Eid, R.A. and B.H. Abou-Leila. 2006. Response of croton plants to gibberellic acid, benzyl adenine and ascorbic acid application. World J. Agric. Sci. 2:174-179.

Francescangeli, N., P. Marinangeli and N. Curvetto. 2007. Paclobutrazol for height control of two Lilium L.A. hybrids grown in pots. Span. J. Agr. Res. 5:425-430.

EUROSTAT. 2015. European Statistics. Available online at http://ec.europa.eu/eurostat

Gashi, B., K. Abdullai, V. Mata and E. Kongjika. 2012. Effect of gibberellic acid and potassium nitrate on seed germination of the resurrection plants *Ramonda serbica* and *Ramonda nathaliae*. Afr. J. Biotech. 11:4537-4542.

Gayakvad, P., D.B. Jadeja and S. Bhalawe. 2014. Effect of foliar application of GA3, ethrel and copper sulphate on flowering behaviour and sex ratio of *Jatropha curcas* L. J. Appl. Nat. Sci. 6:286-289.

Gent, M.P.N. 2004. Efficacy and persistence of paclobutrazol applied to rooted cuttings of rhododendron before transplant. HortScience 39:105-109.

Gholami, M., M. Rahemi and S. Rastegar. 2011. Effect of pulse treatment with sucrose, exogenous benzyl adenine and gibberellic acid on vase life of cut rose 'Red One'. Hort. Environ. Biotechnol. 52:482-487.

Grzesik, M. 1989. Factors influencing the effectiveness of growth regulators in nursery production. Acta Hort. 251:371-375.

Guleryuz, G., S. Kirmizi, H. Arslan and F.S. Sakar. 2011. Dormancy and germination in *Stachys germanica* L. subsp. bithynica (Boiss.) Bhattacharjee seeds: effects of short-time moist chilling and plant growth regulators. Flora Morphol. Distribution Funct. Ecol. Plants 206:943-948.

Gulzar, S., I. Tahir, I. Amin, S. Farogg and S.M. Sultan. 2005. Effect of cytokinins on the senescence and longevity of isolated flowers of day lily (*Hemerocallis fulva*) cv. Royal Crown sprayed with cycloheximide. Acta Hort. 669:395-403.

Hathout, T.A. 1995. Diverse effect of uniconazole and nicotinamid on germination, growth, endogenous hormones and some enzymatic activity of peas. Egypt. J. Physiol. Sci. 19:77-95.

Iqbal, D., U. Habib, N.A. Abbasi and A.N. Chaudhry. 2012. Improvement in postharvest attributes of zinnia (*Zinnia elegans* cv. benary's giant) cut-flowers by the application of various growth regulators. Pak. J. Bot. 44:1091-1094.

Jameson, P.E. and S.F. Clarke. 2002. Hormone-virus interactions in plants. Crit. Rev. Plant Sci. 21:205-228.

Janick, J. 2007. The origins of horticultural technology and science. Acta Hort. 759:41–60.

Keever, G.J. and T.A. Morrison. 2003. Multiple Benzyladenineapplications increase shoot formation in Nandina. J. Environ. Hort. 21:144-147.

Khaimov, A. and Y. Mizrahi. 2006. Effects of day-length, radiation, flower thinning and growth regulators on flowering of the vine cacti *Hylocereus undatus* and *Selenicereus megalanthus*. J. Hort. Sci. Biotechnol. 81:465-470.

Khan, M.A., B. Gul and D.J. Weber. 2004. Action of plant growth regulators and salinity on the seed germination of *Ceratoides lanata*. Can. J. Bot. 82:37-42.

Khandaker, M.M., G. Faruq, M.M. Rahman, M.S. Azirun, and A.N. Boyce. 2013. The influence of 1-triacontanol on the growth, flowering, and quality of potted bougainvillea plants (*Bougainvillea glabra* var. ''Elizabeth Angus'') under natural conditions. Sci. World J. 2013:1-12.

Krug, B.A. 2004. The chemical regulation of bulb crops using flurprimidol as foliar sprays, substrate drenches and pre-plant bulb soaks. M.Sc. diss., Dept. Hort. Sci., North Carolina state University, America.

Krug, B.A., B.E. Whipker and I. McCall. 2006. Hyacinth height control using bulb soaks of flurprimidol. HortTechnology 16:370-375.

Larson, R.A., C.B. Thorne, R.R. Milks, Y.M. Isenberg and L.D. Brisson. 1987. Use of ancymidol bulb dips to control stem elongation of easter lilies grown in pine bark medium. J. Amer. Soc. Hort. Sci. 112:773-777.

Laskowska, H., E. Pogroszewska, W. Durlak and D. Kozak. 2013. The effect of bulb size and application method of asahi SL biostimulator on the growth and yield of *Allium moly* L. Acta Agrobot. 66:89-94.

Latimer, J.G. 2009. Selecting and using plant growth regulators on floricultural crops. College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University, Virginia.

Lawson, R.H. 1996. Economic importance and trends in ornamental horticulture. Acta Hort. 432:226-237.

Lee, S.W. and K.H. Rho. 2000. Growth control in 'New Guinea' impatiens (*Impatiens hawker* hybrida) by treatments of plant growth retardants and triazole fungicides. Kor. J. Hort. Sci. Technol. 18:827-833.

Leeson, T. and R. Harkess. 2006. Influence of cytokinins on lateral branching of *Iris germanica* rhizome. SNA Res. Conf. Proc. 51:330-331.

Leopold, A.C. 1955. Auxins and plant growth. University of California press, California, USA.

Lieth, H., and L.L. Dodge. 2004. Efficacy and phytotoxicity of Fascination (6-benzyladenine and GA4+GA7) on a variety of ornamental plants. Proceedings of the 32nd Annual Meeting of the Plant Growth Regulation Society of America, Newport Beach, California, USA, 24-27 July, 2005 Research Triangle Park:52.

Lodeta, K.B., S.G. Ban, S. Perica, G. Dumicic and L. Bucán, 2010. Response of poinsettia to drench application of growth regulators. J. Food Agr. Env. 8:297-301.

Magnitskiy, S.V., C.C. Pasian, M.A. Bennett and J.E. Metzger. 2006. Controlling plug height of verbena, celosia, and pansy by treating seeds with paclobutrazol. HortScience 41:158-161.

Mahgoub, M.H., A.H. El-Ghorab and M.H. Bekheta. 2006. Effect of some bioregulators endogenous phytohormones, chemical composition, essential oil and its antioxidant activity carnation (*Dianthus caryophyllus* L.). J. Agric. Sci. Mansoura Univ. 31:4229-4245.

Mahgoub, M.H., N.G. Abd El Aziz and M.A. Mazhar. 2011. Response of *Dahlia pinnata* L. plant to foliar spray with Putrescine and Thiamine on growth, flowering and photosynthetic pigments. Am. Eurasian J. Agric. Environ. Sci. 10:769-775.

Market News Service. 2012. Cut flowers and ornamental plants. Available online at http://www.intracen.org/uploadedFiles/intracenorg/Content/Exporters/Market_Data_and_Information/Market_Insider/Cut_Flowers_and_Ornamental_Plants/Floriculture_Monthly_M02_12.pdf

Martin-Mex, R., E. Villanueva-Couohb, T. Herrera-Camposb and A. Larque´-Saavedra. 2005. Positive effect of salicylates on the flowering of African violet. Sci. Hortic. 103:499-502.

Matsumoto, T.K. 2006. Gibberellic acid and benzyladenine promote early flowering and vegetative growth of Miltoniopsis orchid hybrids. HortScience 41:131-135.

Meijon, M., R. Rodríguez, M.J. Canal and I. Feito. 2009. Improvement of compactness and floral quality in azalea by means of application of plant growth regulators. Sci. Hortic. 119:169-176.

Memon, N., M. Qasim, M.J. Jaskani, A.A. Khooharo, Z. Hussain and I. Ahmad. 2013. Comparison of various explants on the basis of efficient shoot regeneration in gladiolus. Pak. J. Bot. 45:877-885.

Moneruzzaman, K.M., A.B.M.S. Hossain, O. Normaniza, M. Saifuddin, W. Sani and N.B. Amru. 2010. Effects of removal of young leaves and cytokinin on inflorescence development and bract enlargement in *Bougainvillea glabra* var. 'Elizabeth Angus'. Aust. J. Crop Sci. 4:467-473.

Parivar, F., J.E. Preece and G.D. Coorts. 1985. The effect of ancymidol concentrations and application methods on cultivars of mid-century hybrid lilly. J. Hort. Sci. 60:263-268.

Percival, G.C. and S. Barnes. 2004. Auxins and water-retaining polymer root dips affect survival and growth of newly transplanted bare-rooted European Beech and Silver Birch. J. Environ. Hort. 22:183-188.

Pill, W.G. and J.A. Gunter. 2001. Emergence and shoot growth of cosmos and marigold from paclobutrazol-treated seed. J. Environ. Hort. 19:11-14.

Pozo, M.J., L.C. Van Loon and C.M.J. Pieterse. 2005. Jasmonates - Signals in plant-microbe interactions. J. Plant Growth Regul. 23:211-222

Rademacher, W. 1991. Inhibitors of gibberellin biosynthesis: Applications in agriculture and horticulture, pp.296-310. In: N. Takahashi, B.O. Phinney and J. MacMillan (eds.), Gibberellins. Springer-Verlag, New York.

Ramzan, F., A. Younis, A. Riaz, S. Ali, M.I. Siddique and K.B. Lim. 2014. Pre-planting exogenous application of gibberellic acid influences sprouting, vegetative growth, flowering, and subsequent bulb characteristics of 'Ad-Rem' tulip. Hort. Environ. Biotechnol. 55:479-488.

Ranwala, A.P., G. Legnani, M. Reitmeier, B.B. Stewart and W.B. Miller. 2002. Efficacy of plant growth retardants as preplant bulb dips for height control in LA and oriental hybrid lilies. HortTechnology 12:426-431.

Ranwala, N.K.D., A.P. Ranwala and W.B. Miller. 2005. Paclobutrazol and uniconazole solutions maintain efficacy after multiple lily bulb dip events. HortTechnology 15:551-553.

Rehman, S. and I.H. Park. 2000. Effect of scarification, GA and chilling on the germination of goldenrain-tree *(Koelreuteria paniculata* Laxm.) seeds. Sci. Hortic. 85: 319-324.

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

Robinson, F.A. 1973. Vitamins, pp.195-220. In: L.P. Miller (ed.), Phytochemistry. Van Reinhold Co., New York.

Sajjad, Y., M.J. Jaskani, M. Qasim, A. Mehmood, N. Ahmad and G. Akhtar. 2015. Pre-plant soaking of corms in growth regulators influences the multiple sprouting, floral and corm associated traits in *Gladiolus grandiflorus* L. J. Agric. Sci. 7:173-181.

Sajjad, Y., M.J. Jaskani, M.Y. Ashraf, M. Qasim and R. Ahmad. 2014. Response of morphological and physiological growth attributes to foliar application of plant growth regulators in gladiolus "White Prosperity". Pak. J. Agri. Sci. 51:123-129.

Sanderson, K.C., W.C. Martin Jr. and J. McGuire. 1988. Comparison of paclobutrazol tablets, drenches, gels, capsules, and sprays on chrysanthemum growth. HortScience 23:1008–1009.

Saniewski, M., J. Goraj, E.W. Lesiak, H. Okubo, K. Miyamoto and J. Ueda. 2010. Different growth of excised and intact fourth internode after removal of the flower bud in growing tulips: focus on. J. Fruit Ornam. Plant Res. 18:297-308.

Schnelle, R.A. and J.E. Barrett. 2010. Paclobutrazol concentration and substrate moisture status impact efficacy of liner dips for size control of three bedding plants. HortTechnology 20:735-739.

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

Stover, E.W. and D.W. Greene. 2005. Environmental effects on the performance of foliar applied plant growth regulators: A review focusing on tree fruits. HortTechnology 15:214-221.

Sugiura, H. 2004. Effects of 6-benzylaminopurine and ethephon applications on flowering and morphology in summer-to-autumn-flowering chrysanthemum under open field conditions. J. Pestic. Sci. 29:308-312.

Taha, R.A. 2012. Effect of some growth regulators on growth, flowering, bulb productivity and chemical composition of iris plants. J. Hortic. Sci. Ornam. Plants 4:215-220.

Thimann, K.V. 1948. Plant growth hormones. The Hormones: Physiology, Chemistry and Applications. Academic Press, Inc., New York.

Wang, J. and V.R. Walter. 2006. Effect of vernalization and plant growth regulators on flowering of Ornithogalum 'Chesapeake Snowflake'. Agric. Sci. Tech. 7:23-28.

Warner, R.M. and J.E. Erwin. 2003. Effect of plant growth retardants on stem elongation of hibiscus species. HortTechnology 13:293-296.

Whipker, B.E. 2013. Plant growth regulator guide. Growertalks, pp.1-37.

Whipker, B.E., I. McCall, J.L. Gibson and T.J. Cavins. 2003a. Efficacy of flurprimidol (topflor) on bedding plants. Acta Hort. 624:413-418.

Whipker, B.E., J.L. Gibson, T.J. Cavins, I. McCall, and P. Konjoinan. 2003b. Growth regulators. Ball redbook. Ball Publishing, Batavia.

Whipker, B.W., B.A. Krug, and I. McCall. 2005. Pre-plant tuber soaks of 6-benzyladenine ineffective for chemical de-eyeing of Caladium. Pl. Gr. Reg. Soc. Am. Quart. 33:16-20.

Witomska, M., A. Jaszczuk and A. Ilczuk. 2010. Branching stimulation in *Hosta* sp. Horticult. Landsc. Architect. 31:35-41.

Wroblewska, K. and R. Debicz. 2013. Influence of time of benzyladenine application on rooting of cuttings and subsequent development of *Portulaca umbraticola* kunth. Acta Sci. Pol. 12:89-99.

Yoon, M.J., K.B. Park and C.H. Pak. 2002. Effects of growth regulators and temperature on the growth of pseudo bulbs in *Bletilla striata*. Korean J. Hortic. Sci. 20:120-123.