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Physiological stresses and phyto-hormones: Effects on the flowering process and longevity of bougainvillea

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A wide variety trait of Bougainvillea genus has made it a decent potential as a new ornamental plant. Different type of foliage, many inflorescence, continuous bloom, first growing and short production cycle of bougainvillea plants that make them attractive to the floriculture industry. Therefore, the longevity of flowers and leaves are crucial nowadays. Apart from the external appearance, the length of their vase-life has become one of the most important criteria in evaluating their quality. Petal colour and its variations also regulate the acceptance of flowers in high competitive flower market. Several researches have been carried out throughout the world on how to improve flower size, petal colour, flower bloom cycle and flower longevity. Many horticultural techniques have been conducted for different flowering and ornamental plants but there is very few literatures are found on flower quality and longevity of bougainvillea. Therefore, few methods such as physiological stresses and phyto-hormone spraying to enhance plant growth, development, flowering process and longevity of bougainvillea have been discussed in this review article

Keywords: Bougainvillea, Pruning, Phyto-hormone, Flowering process, Longevity

INTRODUCTION

Bougainvillea is a flowering plant genus which belongs to the family of Nyctaginaceae and native in South America (Saifuddin et al. 2010). Suxia et al. (2009) reported that bougainvillea have eighteen species and all the species generally used in beautification for the arid landscapes, agriculture, horticulture, environmental industries and pharmaceutical industries, on account of the large flexibility in different agro climatic regions of the world. Recently, it has been reported that bougainvillea is a pollution tolerant plant and can help in the mitigation of air pollution causes of greenhouse gases. Therefore, bougainvillea plants are recommended to planting in urban and industrial areas where the air and sound pollution is very high. The plant can easily adapt to various growing condition and it can be planted in polluted soil, central verge, traffic island, and various other industrial and ecotourism places (Kulshreshtha et al. 2009). As its massive scope, introduction and variation of bract color and size are highly preferable.

It has been stated that environmental factors revealing seasonal changes and create significant effect to control the flowering (Ana et al. 2004). Intensity of light, day length, temperature, nutrient

availability and stress are the most important environmental factors that influence the flowering of plants. With regards to light, the quality, quantity and duration are all important variables that can regulate the flowering. Stirling et al. (2002) reported that temperatures are perceived in different parts of the plant during the control of flowering photoperiod.

Some other besides environmental factors, has been found to stimulate flowering or frequent flowering such as plant growth regulators, growth promoting chemicals, removal of young leaves, girdling, pruning, dwarfing and different stress (Saifuddin et al. 2009a). Recently, it has been stated that the foliar spray of 1-Triacontanol stimulates growth, enhances flowering, and improves the quality of potted Bougainvillea plants (Khandaker et al. 2013) In most experiments, the best results have been achieved with application of GA_3 mixture along with some additional treatments, girdling, root pruning, fertilization and water stress (Saifuddin et al. 2009a).

Delaying Flower Drop

Flower longevity or vase life is the most important character that affects the commercial value of flowers or other ornamental plants (Saifuddin et al. 2009b). Commercial value of flowers could be improved by lengthening the longevity of flower and improving its quality in such as petal color and size (Tjosvold et al. 1994). Vase life of flower is related to petal and leaf senescence, and it is caused by rapid production of ethylene after harvesting from the mother plant (Serek et al. 2006*)*. Sometimes, microbial infection, bacterial colonization and air embolisms also affect the vase life of flowers. Application of GA_3 and ethylene inhibitor hormone NAA individually or its combination in low concentration at the different developing stages, flowering time and transported periods increased the longevity of flowers (Hye and William, 2009). Therefore, the effect of hormone spray, pruning and shading on the plant growth, flowering process as well as biochemical and physiological changes of bougainvillea plant need to be discussed to promote flower size and delay flowers drop. The objectives of this review paper are to discuss the flowering process and consequently its appreciable longevity by applying physiological stresses and phyto-hormones.

Physiological stresses on plants life and flower Initiation: Impact of pruning on plants life

Pruning can be used to improve tree shape, to influence its growth, flowering and fruitfulness, to improve fruit quality, to repair injury, to contain the plant and to increase light and spray penetration (Jean et al. 2007). The ultimate goal of pruning is to improve light distribution so that more tree canopies would maintain high quality flowers and fruits production. In recent years, flower growers and pomologists have been interested in pruning as a mean of growth control when dwarfing rootstocks do not adequately control tree size. Bougainvillea plants respond well to pruning. The shoots of the plants grow vigorously that why regular pruning and thinning is necessary to shape and direct the plant growth. Kent et al. (2007) reported that pruning should be carried out immediately after flowering because pruning promote the new growth which next flush of flowers would occur.

It has been reported that pruning stimulated many metabolic sinks that may cause depletion of reserved carbohydrates flowing from lower plant parts to the new developing flower buds (Salakpetch et al. 1990). Low carbohydrate content was adequate to stimulate the new flowering shoots in both pruned and non-pruned plants. It was also reported that pruned plants have a higher turgor than the non-pruned plants. An offset benefit of a smaller canopy might be the reduced canopy of water consumption and improved tree water status due to a lower canopy transpiration. A reduction in canopy leaf area whether occurs naturally or artificially by pruning, was expected to raise new leaf, soil water potentials and reduce loss of water (Khan et al. 1998).

Flowering ornamental plant bougainvillea can be pruned at any time of the year. Initiation of flower depends upon pruning of the plant and bud formation cycle followed by a certain period after pruned. In winter season, a hard pruning is recommended to prepare the plant for indoor condition. For maintain continuous blooming of bougainvillea need to do soft pruning. Gordon (2002) reported that vine type bougainvillea plant continue to grow outward without sending out side branches from each leaf-bud point unless the stem is pinched. Johnson et al. (1993) stated that flowering and vegetative growth of plant can be modified by training and pruning. Pruning also regulated the position of flower with regard to vegetative growth, e.g. heading cuts may

dissociate flowering from vegetative parts by stimulate vegetative growth in the outer canopy of the tree and enhanced flower bud formation in inner canopy (Calatayud et al. 2002). This might have deleterious effects on flowers and fruits quality.

Figure 1. Different type of girdling or phloemic stress affect flowering behaviour of plant (Adopted from Khandaker et al. 2012)

Impact of phloemic stress on plants life

There are so many horticultural techniques that are involved in making dwarfed trees. Partially ringed bark strip is an important technique among them. Ringing or removal of bark as is a horticultural practice used to manipulate tree physiology, growth, and fruit formation in a variety of fruit species. Dwarfed, compact, or small size trees provide for easier pruning, thinning, spraying, fertilizer application, control of insect pest, harvesting, quality fruit and less cost of production. It has been reported that phloemic stress treatments decreased the vegetative growth and increase the flowering in mango (Jose, 1997). A higher trunk circumference above the girdle may be caused by swelling of the trunk due to the accumulation of carbohydrates (Onguso et al. 2004). They also reported that ringing or phloemic stress blocked the translocation of sucrose from leaf to root through the phloem bundles. However, in unfavorable condition a severe girdling from the stems killed the plants and partial phloemic stress weakened the plants growth and development. Khandaker et al. (2012) reported that different types of girdling or phloemic stress improve the quality of plant parts by increasing colour and accumulation of dry matter in leaf, flower and fruits. Bark ringing tended to dwarf the tree, induced flower bud formation, and promoted fruiting in peach trees (Hossain, 2006). It has been also reported that girdling applied before flowering enhanced inflorescence development and quality of fruits (Khandaker et al. 2011).

Hormonal effects on Bougainvillea: Impacts of GA_3

Gibberellic acid (GA_3) application also has the potential to control vegetative growth, flowering and enhance earliness. GA_3 treatment increased length of petiole and leaf area of strawberry. Several researcher reported that application of GA_3 stimulate flowering in a wide range of plant species. Many species that flower early in response to both GA_3 and long days or vernalization, raising the possibility that GA_3 may be involved in these responses. This response to exogenous GA_3 is paralleled to the effect of photoperiod and vernalization on GA_3 metabolism. Gibberellins played a role in floral initiation and development. The buds on the upper surface of the tuber uptake more gibberellin than the other surfaces. At higher gibberellin concentration and treatment duration increased the proportion of shoots that initiated inflorescences. It has been reported that gibberellin increased in the proportion of initiated flowers that subsequently emerged and the proportion of axillary buds that initiated flowers.

It was also found that the percentage of changed flower colors was altered in the subsequent clonal generation vis-à-vis the effect also diminished with the passage of time. GA plus

kinetin also had a significant effect on improving flower longevity at the mature (fully colored) bud, but produced a lesser effect when applied to green immature buds. It has been reported that sucrose and kinetin application increased flower quality and increased the vase life and Bougainvillea flower (Moneruzzaman et al. 2010a)

S.No	Growth regulators	Effects	References
1	GA_3	Development of stamens and petals during flower development and expansion	Saifuddin et al. 2009a
2	GA_3	Reduced the time needed for flower emergence, promote flowering and increased the number of flower buds and bloom flowers	Sharma and Room, 2009
3	GA_3	Stimulated more rapid flowering	Brooking and Cohen, 2002.
4	GA_3	Increase the number and size of flower	Ogale et al. 2000
5	GA_3	Enhanced the early flowering and decreased the number of leaf	Xingjun et al. 2003
6	GA_3	Blooming rate of Bougainvillea	Khandaker et al. 2015
7	GA_3	Increased hydrolysis of starch and sucrose into glucose and fructose which are utilized by flowers for opening of disc floret.	Fernfindez et al. 1997
8	Kinetin	Increased flower bud formation and improved the longevity of Bougainvillea flower	Moneruzzaman et al. 2010b
9	1-Triacontanol	Stimulate the flowering and increased the size of Bougainvillea bract	Khandaker et al. 2013
10	GA_3	Increased the flowering, fruit formation and colour development	Moneruzzaman et al. 2011a

Table 1: Effects of growth regulators on flower formation, flower quality and longevity

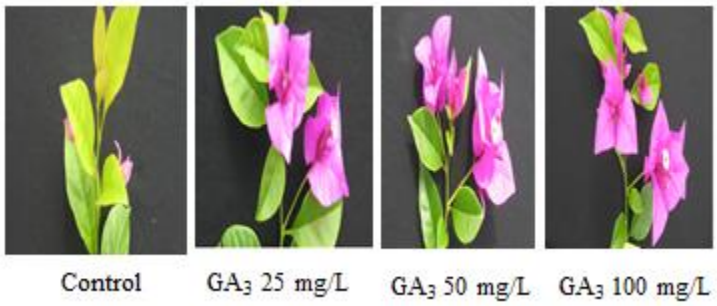

Figure 2: Effect of different concentration GA_3 on blooming rate of Bougainvillea (Adopted from Khandaker et al. 2015)

Figure 3: Effect of different concentration GA_3 on bract size of Bougainvillea (Adopted from Khandaker et al. 2015)

Flower composed of several floral parts, is a heterogonous organ and all this floral part are in different physiological stages. Gibberellin present at different concentrations in different floral parts of same flower. It has been reported that GA_3 significantly increased the number of disc florets but decreased the dry matter content in flower heads and stems.

It also been reported that removal of young leaf and cytokinin treatment promote the flower bud development and increased the bract quality of Bougainvillea (Moneruzzaman et al. 2010b). Turgidity maintenance is an important technique in lengthening of shelf life of gerbera cut flowers. Xingjun et al. (2003) reported that carbohydrates content and dry weight of petals are decline at the final stages of flower development. Besides horticultural techniques, genetic and environmental factors also affect the flowering behavior of several ornamental plants (Moneruzzaman et al. 2011)

Emongor (2004) stated that gibberellins increase hydrolysis of starch and sucrose into glucose and fructose, which were utilized by the flowers for floret opening and expansion of petal. Naphthalene Acetic Acid in presence of GA_3 delayed bract abscission and color fading of bougainvillea bract because of increased the hydrolysis of TSS by GA_3 which delayed petal senescence and color fading. Zhu and Davies (1997) stated that may be NAA to interact with GA_3 and hence delaying the abscission of flower by either delaying the natural rise in ethylene production or by altering the sensitivity of the tissue to ethylene or both.

Ethylene effects on flowers longevity

A number of developmental factors regulate the ethylene production and it can be induced by many physiological, chemical and environmental stressess during germination, growth, senescence of leaf and flowers and ripening of fruits. Besides acting as a plant hormone influencing many aspects of plant growth and development, it is also one of the natural occuring plant growth regulatory substances (PGRS) or famously known as phytohormones (Bleecker and Kende, 2000). This simplest carbon atom compound is a dominant regulator of plant growth, metabolism, and interacting with other plant growth regulators in trace amounts. Ethylene is the key phytohormone in promoting senescence in cut flowers and causes fruit ripening. This directly reduces quality and display life of flowers. Ethylene was a natural plant product where it could induce senescence in plants. Ethylene also play a significant role in regulating the physical, biochemical and cellular changes that constitute the post-pollination syndrome in Phalaeopsis (Beatriz and James, 2008). It acts by inhibiting respiration, decreasing cell wall material and lipids, and increasing sugar levels of the plants. In general, it appears to hasten senescence plant organs and accelerate the abscission process (Redman et al. 2002).

Investigation by other researchers also proved that ethylene production increased during flower senescence and ethylene accelerates flower senescence (Celikel et al. 2002). It is devidid into three phases which corresponds to the three phases of senescence. The first phases is the pre-climacteric phase, the concentration of ethyene metabolized by the tissues is extremely a little and the respiration rate is a stable (Kosugi et al. 2000). Ethylene production occurus in all plant organs including flower but the magnitude of its production varies and depends of growth and development process. Recent scientific process has made clear the understanding of biosynthetic pathway and enzymes involment in ethylene production (Kenza et al. 2000).This autocatalytic effect of ethylene could be very pronouced and lead to loss of quality during transporation and storage (Van Door, 2001). The vase life of bougainvillea flowers could be extended by silver thiosulfate (STS), an inhibitor of ethylene action (Chang and Chen, 2001). Their findings suggested that ethylene regulated sepal

abscission in bougainvillea. Patterson and Bleecker (2004) reported that abscission is a typical ethylene response that is alleged by ethylene receptors and is regulated by mutations in ethylene receptor genes. Flower longevity is one of the most important traits of ornamental plants and the lengthening of longevity is an ongoing target for plant breeders and horticulturist (Onozaki et al. 2001).

Synthetic auxin- NAA as ethylene inhibitor

For preventing the deteriorative effect of ethylene on postharvest behavior of ornamental plants a range of methods and chemicals is used. Interfering with the plant response to ethylene can be achieved by inhibition of plants own ethylene production inhibition, blocking the binding of ethylene to its receptor and blocking the plant's reaction to the binding of ethylene to the receptor. Common used chemical is silver thiosulfate (STS) but its toxicity is high. Now, another chemical, naphthalene acetic acid (NAA) is mostly used due to its low toxicity level (Dimitrios et al. 2008).

It has been reported that leaf chlorophyll content, net photosynthetic rate and drymatter content of wax apple plant leaves increased significantly with NAA application (Khandaker et al. 2015). All of these improved physiological activities play a significant role to promote flowering and longevity in the plant. Foliar application of NAA increased the flowering and fruit number of tomato plants. Khandaker et al. (2017) reported that application of 25 mg/L NAA improved the plant physiological activities and stimulate flowering as well as flower number of Mokara Chark Kuan orchid flowers. Normanly (1997) reported that the regulatory effects of plant hormone depend on the stage of plant development. NAA treatments also prevent the sprouting of stems and bulb of ornamental plants. Chang and Chen (2001) reported that application NAA at the cut tip of ornamental plants suppressed the growth of lateral bud and this adaption is manipulated to cultivate beautiful ornamental plants.

CONCLUSION

Growth manipulating techniques are being constantly changed and improved to meet the demands of individual species and cultivars of flowering plants. Each flowering plant needs a specific approach, and at the same time it should be as simple as possible. In this current research, the effect of growth regulators such as gibberellic acid (GA_3) and NAA and the plant manipulation tactic by heading pruning to improve the flowering pattern were discussed on *Bougainvillea* spp. It can be concluded based on the current research review, soft frequent pruning is the effective methods to induce frequent flowering and prolong vase life of bougainvillea bract. Exogenous applications of GA_3 increase bract size and prolong the vase life of Bougainvillea.

CONFLICT OF INTEREST

The authors declared that present study was performed and published in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Designed the review paper MS and MMK. Wrote the paper MS and MMK. Reviewed and edited the paper KM and MHS. All authors read and approved the final version.

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