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# Foliar application of plant growth regulators affecting vegetative and flowering traits in mop-head hydrangea (*Hydrangea macrophylla*)

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## ABSTRACT

*Hydrangea is one of the world's most charming and wonderful ornamental plants. In recent years hydrangeas have been used commonly as cut flowers, potted plants, and garden plants with a gradual increase in popularity and production worldwide. The present study was conducted to investigate the effect of foliar application of plant growth regulators on Hydrangea macrophylla. The study provides valuable information for optimizing hydrangea growth and development through the use of PGRs. It focuses on the factors such as plant height, flower size, and overall aesthetics. The treatments comprised of different plant growth regulators at different concentration i.e., gibberellic acid ($GA_3$: 25 ppm, 50 ppm, and 100 ppm), benzyladenine (BA: 50 ppm, 100 ppm, and 150 ppm and giberellin in combination with benzyladenine ($GA_{4+7}$@ +BA: 50 ppm, 150 ppm, and 250 ppm). From the data, it was revealed that the use of different PGRs had a significant effect on all the vegetative and floral parameters of the plants. The plants treated with $GA_3$ @ 100 ppm had maximum plant height (39.60 cm), the maximum length of shoots (27.51 cm), minimum days taken for visible bud formation (151.47 days), and minimum days for flowering (184.53 days). In addition, maximum pot presentability (88.17) and growth index (35.81) were recorded in the plants with the application of $GA_{4+7}$@ 50 ppm+BA @ 50 ppm. Thus, the study indicated that hydrangea plants treated with $GA_{4+7}$ @ 50 ppm + BA @ 50 ppm resulted in the most desirable and presentable potted plants. By providing insights into the effective use of PGRs, the study can help growers optimize plant production, improve plant quality etc.*

***Keywords:*** *Hydrangea, PGRs, Optimizing growth, Quality production.*

## INTRODUCTION

Hydrangea (*Hydrangea macrophylla*), also known as mop head or big leaf hydrangea, is a member of the family Saxifragaceae. This family consists primarily of woody plants, with 17 genera and approximately 170 species [9]. *Hydrangea macrophylla* is one of the most popular species that is commercially cultivated [15]. It is used as a deciduous, attractive woody shrub in landscapes or as a flowering potted plant for interior scapes and residences [6]. Hydrangeas are primarily grown for the spring pot plant market, but they have become a commercially viable venture in the same way that roses, chrysanthemums, and carnations have. These are prized for their massive, spherical flowerheads, which come in a range of colors from white, and purple to pink and red [16]. A chilly, damp temperature is beneficial for its growth and development. It can endure light conditions in the landscape ranging from mild sun to deep shadow, though it will not flower as profusely in the latter [29]. It produces blue flowers in acidic soils, pink flowers require a pH of 5.8-6.4 or more alkaline [5], whereas white flowers are found in neutral soil.

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Growers nowadays force hydrangea to obtain blooms during late January and February or around the year. Production schedules to meet demand for Christmas, Valentine's Day, Easter, and Mother's Day markets [30]. To meet such demands the use of PGRs has been introduced. These are the chemical substances that regulate and modify the physiological processes of plants at a low concentration. PGRs can be used for advancing or delaying flowering and also to induce uniform flowering in several flower crops. These are easily absorbed by the plants and have fast movement through the plant tissues when application on different parts of the plant is done. Synthetic plant growth regulators like auxin, gibberellins, and cytokinins are most commonly used by people as they are stable and readily available in the market [25]. PGRs are now being utilized by commercial growers of ornamental plants as a part of cultural practice to manipulate the plant according to the market trend grower and consumer or according to the changing trend in the market, which helps to improve the plant's economic value [31]. PGRs used in improving crop quality and productivity are becoming more popular. Hernandez (1997) reported that plant growth regulators have positively enhanced the growth and yield of plants. However, these compounds show different responses in different crops according to the concentration and composition used[19].

## MATERIALS AND METHODS

### Experimental material, Site and Design

The experimental was carried out during 2020-2021 and 2021-2022 at Horticulture Research & Training Station and KVK Kandaghat, Solan which is situated in the northern hemisphere at a latitude of $30.97^0$ and longitude $77.10^0$ at an elevation of 1425m with sub temperate climate. The area falls under zone 2 (sub-humid mid hills) of agroclimatic zones of Himachal Pradesh (India).

In this study one year old healthy, disease free and uniform size stock plants of *Hydrangea macrophylla* were selected. These stock plants were prepared from softwood terminal cuttings taken from healthy and vigorous mother plant in the month of July. The stock plants of hydrangea were planted in 8 inches plastic pots containing a sterilized potting media during. The media consisted of pine wood soil, FYM, sand, pine needle leaf mould and shredded pine tree bark (2:1:1:1:1 v/v). Basal application of NPK (2.5g N, 1g P and 1.5g K per pot) was done. Full dose of phosphorous and potassium and one fourth dose of nitrogen was given at the time of planting/ potting. Apart from this, fertigation of plants was also done at fortnightly intervals @ 200 ppm through NPK- 19:19:19. To reduce chances of iron deficiency in hydrangea plants, foliar application of ferrous sulphate EDTA was done 2g/ L at fortnightly interval. To maintain the health and pot presentability the standard plant protection measures were followed.

The spraying solution of different concentrations of PGRs was prepared in distilled water just before foliar application. There were total of ten treatments (Control- $T_1$, $GA_3$ @ 25 ppm -$T_2$, $GA_3$ @ 50 ppm -$T_3$, $GA_3$ @ 100 ppm- $T_4$, BA @ 50 ppm -$T_5$, BA @ 100 ppm -$T_6$, BA @ 150 ppm -$T_7$, $GA_{4+7}$ @ 50 ppm + BA @ 50 ppm- $T_8$, $GA_{4+7}$ @ 150 ppm + BA 150 ppm -$T_9$, $GA_{4+7}$ @ 250 ppm + BA @ 250 ppm- $T_{10}$). Three foliar applications of PGR were done at 15 days interval when the plants were in their vegetative phase. The sprayer nozzle was set to the finest point to give an even mist. The plant growth regulators were sprayed uniformly over the plants till then droplets of solution were trickling down. The control plants were sprayed with distilled water. Spraying was done in evening hours. One liter of solution was required for each treatment.

The data generated from the present investigation on various vegetative and flowering parameters were subjected to analysis of variance using completely randomized design at five per cent level of significance [12].

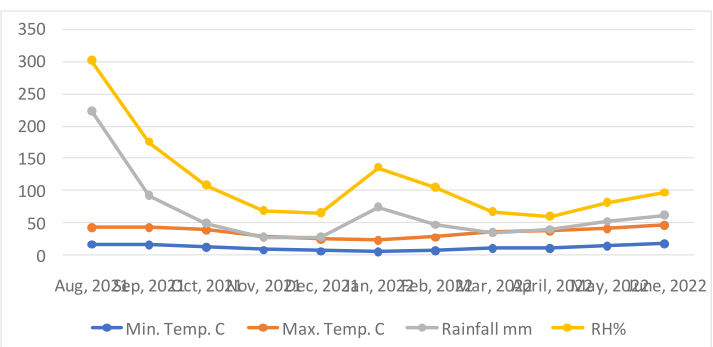


*Fig 1. Monthly Average Meteorological data of the experimental area during the research period August 2021- June 2022*


*Flower at initial and peak pigment*

**Various developmental stages of inflorescence of *Hydrangea macrophylla***

## RESULT AND DISCUSSION

### Plant Height (cm)

The effect of plant growth regulators on the height of the plants has been indicated in Table-I. Compared to other treatments, the maximum plant height (39.60 cm) was recorded in $GA_3$ @ 100 ppm. The increase in plant height with the application of $GA_3$ is due to the cell multiplication and cell elongation properties of gibberellins. It enhances auxin activation by proliferating the site of auxin action i.e., shoot apex. Thus, due to cell elongation the internodal length and number increase which causes an increase in plant height. A similar trend of results was found in gladiolus cv. 'Red Candyman' [1], in *Chrysanthemum morifolium* cv. 'Zambla White' [11] where maximum plant height was recorded when plants were treated with $GA_3$. Also, maximum plant height was recorded when Lilium (*Lilium longifolium*) cv. 'Menorca' plants were sprayed with 100 ppm $GA_3$ [28].

### Plant Spread (cm)

Plant spread is an important agronomical trait that influences plant morphology above ground (Table-I). Plants treated with BA at 150 ppm had the greatest plant spread. The increase in plant spread could be attributed to the physiological action of BA, as BA is known for cell expansion rather than cell elongation, as auxin and $GA_3$ are. Another explanation for greater plant spread could be an increase in the number of lateral shoots. BA promotes cell growth in all directions. There can be a decrease IN apical dominance if cytokinin levels in the plant are elevated [27]. Similar results were obtained in Hybrid Tea Rose cv. 'Bugatti', with the application of BA @ 200 ppm [21].

### Growth Index

The highest growth index (35.81 cm) was seen in plants treated with 50 ppm $GA_{4+7}$ + 50 ppm BA. The growth index increased significantly as compared to the control. This increase in overall plant growth might be due to the combined effect of gibberellic acid and benzyl adenine. Gibberellins regulate axillary meristems, hence influencing plant architecture [10]. The combination of $GA_{4+7}$ + BA promoted lateral growth and caused lateral branch elongation, which improved the overall growth of the treated stock plants. Similar results were seen in *Salvia pachyphylla* and *Osteospermum* hybrid at 50 ppm concentration of $GA_{4+7}$ + BA as compared to other treatments [17].

**Number of shoots**

The data in *Table II* showed that plants treated with BA @ 150 ppm generated a maximum number of shoots per plant (12.15). It was also discovered that increasing the concentration of BA boosted the number of shoots substantially. Shoot regulation or shoot branching is an important part of crop improvement. BA is known to regulate cell division and to play a role in lateral bud outgrowth. Several findings reported that cytokinin synthesized in the stem nodes is responsible for axillary bud outgrowth [8]. The external application of BA enhances the growth of lateral buds and hence counteracts the effect of apical dominance giving rise to more shoots [27]. Similarly, in potted *Miltoniopsis* Orchids [22] and in tea cv. "Longijng 43" [32] showed the same effects with application of BA. Likewise, the number of shoots seen increased with different concentrations of $GA_{4+7}$ **+**BA as compared to control. This might be due to the combined effect of both gibberellins and cytokinin on the physiology of the plant.

**Length of shoots (cm)**

The maximum (27.51 cm) length of the shoots recorded with $GA_3$ @ 100 ppm and the minimum with BA @ 150 ppm was used. Also, *Table-II* shows a significant increase in the length of shoots with an increase in the concentration of $GA_3$ and a decrease with an increase in the concentration of BA. Similar results with a significant increase in the length of shoots with application of $GA_3$ were also observed in *Hibiscus rosa-sinensis* [23] and in rose [27]. As the concentration of BA increases, shoot length decreases, which could be attributed to changes in apical dominance or a drop in endogenous gibberellin levels [7].

**Length of flower stalk (cm)**

The application of several plant growth regulators at diverse concentrations has a substantial effect on the length of the flower stem as presented in table 2. The application of BA resulted in a considerable decrease in flower stem length. The lowest concentration was found in plants treated with BA @ 150 ppm, which could be related to suppression of cell elongation and division at higher concentrations of benzyl adenine. The significance of short flower stalk length is that it will give compact inflorescences. In Amaryllis belladonna cv. "Zephyranthes" [19] and Tuberose cv. "Single" [18] the similar trend was reported.

**Number of days taken for visible bud formation**

From the data recorded it was clear that the plants treated with $GA_3$ @ 100 ppm took minimum days (151.47 days) for visible bud formation. *Table II* shows a significant variation in the number of days taken for visible flower bud formation due to the application of various concentrations of PGRs. Plants treated with $GA_3$ at 100 ppm showed the minimum number of days (151.86) to generate visible buds, it can be due to the fact that gibberellins promote juvenile-to-adult transition when its endogenous levels rises [2]. These results were similar to the findings in African marigolds with $GA_3$ at 100 ppm [24] and in Amaryllis lily with $GA_3$ at 250 ppm [19].

**Number of days taken for flowering**

Hydrangeas where the foliar application of $GA_3$ @ 100 ppm was done reported early flowering i.e., the minimum number of days (*Table-III*.) taken for flowering as compared to other treatments. This can be due to the effect of gibberellins which reduces the juvenile phase and also due to the production of florigen flowering hormone. Thus, causes early development of the flowering stage (reproductive stage) i.e., the shoot apical meristem instead of producing branches and leaves start producing flowers. These results are in concurrence with the findings in *Amaryllis belladonna* [19]. BA-treated plants require the longest time to flower due to a feature of BA that promotes an increase in multiple shooting or lateral branching and occasionally interferes with the production of endogenous auxin and gibberellins. As a result, flowering gets delayed. In gladiolus cv. "Summer Shine" BA showed same result by causing delay in flowering [14].

**Number of in florescences per plant**

Application of BA @ 150 ppm gave the maximum inflorescences per plant (7.20) as compared to other treatments. The increase in number of inflorescences per plant can be due to the production of more shoots per plant. These results were in accordance with work reported in Carnation [3] and the effect of benzyl adenine on growth, flowering, yield and quality of Hybrid Tea rose cv. 'Bugatti' [21]. Another factor could be the indirect action of gibberellins, which produce an increase in the number of leaves and leaf area, which may have aided in the generation and accumulation of assimilates that were translocated from source to sink for flower production.

**Inflorescence diameter (cm)**

Hydrangea plants treated with $GA_3$ @ 100 ppm had maximum inflorescence diameter (12.26 cm**)** whereas the minimum (9.73 cm) inflorescence diameter was recorded in control**.** The increase in inflorescence diameter might be on account to the fact that $GA_3$ enhances translocation of metabolites at the site of flower bud development. This might have led to increase in floret size which eventually increased the diameter of inflorescences. Similar results were recorded in chrysanthemum where they observed the same increase in flower size with application of $GA_3$ [20],[26].

**Duration of flowering (days)**

Plants with a maximum duration of flowering were recorded in treatment with foliar application of BA @ 150 ppm with 86.82 days whereas minimum duration was recorded in control with 65.19 days (*Table III*). From the investigation, it was clear that the period of flowering increased as the concentration of BA increased. This rise could be attributed to the effect of increasing endogenous BA concentration on numerous physiological activities in plant tissue such as membrane permeability, water balance, and protein and nucleic acid metabolism. The optimal concentration of BA may have reduced ethylene production in flowers, extending the length of flowering. These results were similar to the findings in hybrid tea rose cv. "Bugatti" with BA @ 200 ppm [21]. Likewise, an increase in flowering duration with the application of BA @ 200 ppm in chrysanthemum[4].

**Pot presentability**

The data presented in *Table-III* significantly varied with the use of plant growth regulators. The maximum pot presentability (88.17) was recorded where the application of $GA_{4+7}$ @ 50 ppm **+** BA @ 50 ppm was done. This could be due to the combined impact of $GA_{4+7}$ and BA. Their effect resulted in overall plant growth, which comprises plant height, plant spread in harmony with the pot, quantity of inflorescences, and blooming time. Gibberellins may have aided in a variety of physiological processes such as cell elongation and the stimulation of

hydrolytic enzymes that regulate protein and metabolite mobilization. BA, on the other hand, may have boosted the plant's lateral growth, increasing the number of inflorescence shoots, delaying senescence, and prolonging the time of flowering. Thus, the combined effect of gibberellins and cytokinins enhanced the overall growth and flowering of hydrangea. The results were found to be in close proximity with the study conducted on *Salvia pachyphylla* and *Osteospermum* hybrid [17].

## Conclusion

The study found that using plant growth regulators (PGRs) had a substantial impact on both the vegetative and blooming features of *Hydrangea macrophylla*. The application of 50 ppm $GA_{4+7}$ and 50 ppm BA foliar at 15-day intervals throughout vegetative growth resulted in the most attractive and presentable plants. The plants treated with this mixture had excellent growth metrics, such as height, shoot length, and took less time for observable bud formation and blooming. $GA_4+_7$ and BA considerably improved pot presentability and overall growth index, demonstrating their usefulness in growing visually appealing ornamental plants. By carefully selecting and applying appropriate PGRs, growers can manipulate hydrangea growth to achieve desired outcomes. This study will provide valuable insights into the optimal PGRs and application methods for enhancing hydrangea production and meeting market demands.

The study provides a solid foundation for future research and development. By expanding PGR combinations, investigating the effects of environmental factors, exploring sustainable PGR use, integrating precision agriculture technologies, and considering consumer preferences and market trends, future research can contribute to the sustainable and efficient production of high-quality hydrangea plants. These advancements will not only meet the growing demand for ornamental plants but also address the challenges posed by climate change and evolving consumer preferences.

## Compliance with Ethical Standards

Conflict of interest: The authors declare that they have no conflict of interest.

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## Author's contribution

R. T. (Rupali Thakur) conducted the experiment and analyzed the data; R.T. (Rajesh Thakur) conceptualized the research and guided throughout the experiment; C.N.C and B.K. helped in main manuscript writing and forming tables; S.S, T.L. and S. K. helped in data curation.

***Table I. Effect of plant growth regulators on plant height (cm), plant spread (cm) and growth index of Hydrangea macrophylla***

| Treatments Details | Plant height (cm) | Plant spread (cm) | Growth Index |
|---|---|---|---|
| Control | 29.60 | 28.51 | 29.54 |
| $GA_3$ @ 25 ppm | 35.53 | 27.09 | 30.57 |
| $GA_3$ @ 50 ppm | 36.13 | 27.74 | 31.03 |
| $GA_3$ @ 100 ppm | 39.60 | 29.39 | 33.99 |
| BA @ 50 ppm | 33.07 | 29.57 | 30.91 |
| BA @ 100 ppm | 30.53 | 31.17 | 30.43 |
| BA @ 150 ppm | 28.33 | 35.43 | 32.08 |
| $GA_4+_7$ @ 50 ppm + BA @ 50 ppm | 36.67 | 33.96 | 35.81 |
| $GA_4+_7$ @ 150 ppm + BA 150 ppm | 35.27 | 33.11 | 34.16 |
| $GA_4+_7$ @ 250 ppm + BA @ 250 ppm | 33.93 | 33.23 | 33.64 |
| $C.D_{0.05}$ | 1.15 | 1.80 | 1.23 |

***Table II. Effect of plant growth regulators on length of shoots (cm), number of shoots, length of flower stalk and number of days taken for visible bud formation of Hydrangea macrophylla***

| Treatments Details | Length of shoots (cm) | Number of shoots | Length of flower stalk (cm) | Number of days taken for visible bud formation |
|---|---|---|---|---|
| Control | 17.97 | 6.98 | 3.01 | 161.96 |
| $GA_3$ @ 25 ppm | 23.10 | 7.60 | 3.11 | 158.53 |
| $GA_3$ @ 50 ppm | 24.37 | 8.70 | 3.41 | 153.47 |
| $GA_3$ @ 100 ppm | 27.51 | 9.42 | 3.77 | 151.86 |
| BA @ 50 ppm | 17.05 | 10.06 | 3.02 | 163.33 |
| BA @ 100 ppm | 16.36 | 11.28 | 2.85 | 165.60 |
| BA @ 150 ppm | 14.59 | 12.15 | 2.74 | 170.13 |
| $GA_4+_7$ @ 50 ppm + BA @ 50 ppm | 23.81 | 10.57 | 3.27 | 160.33 |
| $GA_4+_7$ @ 150 ppm + BA 150 ppm | 22.70 | 11.07 | 3.11 | 165.97 |
| $GA_4+_7$ @ 250 ppm + BA @ 250 ppm | 22.33 | 11.70 | 3.03 | 169.10 |
| $C.D_{0.05}$ | 1.25 | 0.57 | 0.17 | 2.41 |

*Table III. Effect of plant growth regulators on number of days taken for flowering, number of inflorescences per plant, inflorescence diameter (cm), duration of flowering (days) and pot presentability of Hydrangea macrophylla*

| Treatments Details | Number of days taken for flowering | Number of inflorescences per plant | Inflorescence diameter (cm) | Duration of flowering (days) | Pot presentability (Score out of 100) |
|---|---|---|---|---|---|
| Control | 201.67 | 4.40 | 9.73 | 65.19 | 73.92 |
| $GA_3$ @ 25 ppm | 189.13 | 5.26 | 11.55 | 70.82 | 79.50 |
| $GA_3$ @ 50 ppm | 186.86 | 5.67 | 11.90 | 73.01 | 81.34 |
| $GA_3$ @ 100 ppm | 184.53 | 6.13 | 12.26 | 76.12 | 83.63 |
| BA @ 50 ppm | 203.03 | 6.40 | 11.04 | 79.56 | 80.83 |
| BA @ 100 ppm | 206.37 | 6.53 | 11.70 | 83.96 | 82.76 |
| BA @ 150 ppm | 208.83 | 7.20 | 12.07 | 86.82 | 86.20 |
| $GA_{4+7}$ @ 50 ppm + BA @ 50 ppm | 195.67 | 5.46 | 11.06 | 73.11 | 88.17 |
| $GA_{4+7}$ @ 150 ppm + BA 150 ppm | 197.03 | 5.67 | 10.63 | 69.57 | 84.64 |
| $GA_{4+7}$ @ 250 ppm + BA @ 250 ppm | 199.83 | 6.07 | 10.05 | 66.83 | 81.13 |
| $C.D_{0.05}$ | 3.07 | 0.45 | 1.15 | 1.95 | 3.52 |

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