***Original Research Article***

**Optimizing Pot-Anthurium Growth and Blooms: Exploring the Impact of Plant Growth Regulators**

**ABSTRACT**

The current investigation aimed to produce beautiful pot-Anthurium using plant growth regulators was conducted in the shade-net house of the All-India Co-ordinated Research Project on Floriculture at Odisha University of Agriculture and Technology, Bhubaneswar, from June 2022 to June 2023, with sixteen treatments replicated thrice, in a Completely Randomized Design. The plants were sprayed with Benzyl adenine (BA), Gibberellic acid (GA3) and Cycocel (CCC) at five different concentrations (100 ppm, 200 ppm, 300 ppm, 400 ppm and 500 ppm). The results revealed that plants treated with GA3 @ 500 ppm recorded the highest vegetative growth parameters, including plant height (21 cm), leaf length (7.38 cm), and leaf width (3.26 cm). Other growth parameters, such as the number of suckers per plant (3.8), number of leaves per plant (23) and the plant spread in both East-West (21.32 cm) and North-South (23.2 cm) directions, were maximized in plants treated with BA @ 500 ppm. Floral parameters, including the number of flowers per plant (3.2), spadix length (1.38 cm), spadix breadth (0.36 cm), spathe length (4.46 cm), and spathe breadth (2.82 cm) were recorded highest in plants treated with GA3 @ 500 ppm. Overall, the application of GA3 @ 500 ppm and BA @ 500 ppm exhibited the best results in vegetative growth, flowering habit, quality, and flower production compared to other treatments.

**Keywords:** Anthurium, Growth regulators, GA3, BA, CCC

1. **INTRODUCTION**

Anthurium are tropical plants highly valued for their vibrant cut flowers and ornamental foliage. They have emerged as a significant commodity in commercial farming, capitalizing on a lucrative market for both cut flowers and whole plants. Anthurium, a slow-growing perennial crop with over 100 genera and approximately 1,599 species, predominantly from tropical regions, thrive in shady, humid conditions reminiscent of tropical forests, making them ideal for cultivation in such environments (Muraleedharan *et al.,* 2020).

Anthurium are becoming increasingly favoured due to their ability to provide excellent return per unit area and the allure of their striking, long-lasting flowers. Anthurium accounts for 60% of the cut flower and foliage exports from Mauritius, generating millions in foreign revenue each year, with high demand and respectable pricing both as a cut flower and as a whole plant (Anand *et al*., 2017).

In recent times, the production of pot anthurium has become increasingly significant alongside the conventional focus on cut flower production. While considerable research has been dedicated to the cultivation of cut anthurium, there remains a noticeable dearth of studies addressing pot anthurium. The research addresses the challenge of anthurium cultivation, specifically focusing on pot anthurium. It explores how growth regulators impact the growth and flowering of pot anthuriums.

Nowadays, there has been a significant rise in the use of plant growth regulators. They influence the physiological and morphological processes of vegetables, fruit crops and other plants (Davies, 2004). Gibberellic acid (GA3) is an important group of plant growth regulators within the cytokinin family, commonly referred to as the "cell division hormone." It regulates various physiological processes, including the stimulation of cell division, enlargement of cell, morphogenesis, delaying senescence, promoting chloroplast development, and facilitating nutrient mobilization (Shudo, 1994). Benzyl adenine (BA) found to improve plant yield by influencing growth, flowering, and various physiological processes throughout the plant life cycle (Yadav *et al*., 2021). Recently, BA has been used as an additional source to preserve or improve the condition of a variety of ornamental plants (Gabrel *et al.*, 2018). To create dwarf and visually appealing pot plants, various growth retardants such as Cycocel (CCC), B-Nine, Phosphon, and Anacymidal have been tested on different ornamental species. Cycocel is a synthetic substance that reduce stem growth and prolongs the shelf life of flowers. The foliar application of higher concentrations of CCC leds to phytotoxic effects, with growth retardation becoming more marked as the concentration increased (Singh *et al*., 2018). These regulators, readily available in the market, play a significant role in influencing the growth and flowering attributes of pot anthurium. Despite advancements in the anthurium industry in India, comprehensive research on systematically cultivating pot anthuriums, with an emphasis on foliar applications of growth regulators, is still limited.

This research seeks to evaluate vegetative and flowering parameters, placing special emphasis on the effect of growth regulators like BA, GA3, and CCC with the overarching goal of enhancing pot anthurium cultivation under protected conditions.

1. **MATERIALS AND METHODS**

The experiment was conducted during 2022-23 to study the effect of plant growth regulators on growth and flowering of pot anthurium. It was carried out under the shade-net house of the All-India Co-ordinated Research Project on Floriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India.

The experiment was laid out following completely randomized block design, with three replications and sixteen treatments. Uniform plants of pot anthurium (10 cm high), raised through tissue culture were chosen for this experiment. The plants were planted in 6-inch earthen pots in a substrate containing cocopeat: perlite: sand in the ratio 10: 1: 1. All plants were sprayed uniformly with a nutrient mixture of 20:20:20 (water soluble NPK) @ 20 g/L on alternate days and micro-nutrient @ 1 mL L-1 was sprayed at 15 days interval. One month after planting, the plants were sprayed with different concentration of BA, GA3 & CCC as per the details given in table 1.

**Table 1: Concentration of spray solutions in different treatments.**

|  |  |
| --- | --- |
| **Treatment** | **Treatment Details** |
| T1 | Control |
| T2 | BA @ 100 ppm |
| T3 | BA @ 200 ppm |
| T4 | BA @ 300 ppm |
| T5 | BA @ 400 ppm |
| T6 | BA @ 500 ppm |
| T7 | GA3 @ 100 ppm |
| T8 | GA3 @ 200 ppm |
| T9 | GA3 @ 300 ppm |
| T10 | GA3 @ 400 ppm |
| T11 | GA3 @ 500 ppm |
| T12 | CCC @ 100 ppm |
| T13 | CCC @ 200 ppm |
| T14 | CCC @ 300 ppm |
| T15 | CCC @ 400 ppm |
| T16 | CCC @ 500 ppm |

Note: T: Treatment; BA: Benzyl adenine; GA3: Gibberellic acid; CCC: Cycocel; ppm: Parts Per Million

A 1000 ppm stock solution for each of BA, GA₃, and CCC was prepared by dissolving 500 mg of each substance in its designated solvent: BA in a small volume of 0.1N NaOH, GA₃ in ethyl alcohol, and CCC in distilled water, with each solution was brought to a final volume of 500 ml using distilled water. To prepare solutions of 100, 200, 300, 400, and 500 ppm, respective volumes of 10, 20, 30, 40, and 50 ml from each stock solution were diluted to 100 mL with distilled water. Prior to application, the pH of each spray solution was adjusted to a range of 5.7–5.8 using 0.1N HCl or NaOH.

First spray was done one month after planting, followed by subsequent sprays at 15-days interval. For recording various growth and flowering parameters, five plants in each treatment were selected at random. Various growth and flowering parameters like plant height (cm), number of leaves per plant, number of suckers per plant, plant spread (cm), leaf length and width (cm), number of flowers per plant, spadix length (cm), spadix breadth (cm), spathe length (cm), spathe breadth (cm), spathe colour were recorded.

The experiment was laid out with complete randomized design and ANOVA was calculated using the observations recorded on different growth and floral parameters, following this design, at 5% level of significance. The statistical method described by Gomez and Gomez (1984) was used to evaluate the recorded data.

1. **RESULTS AND DISCUSSION**

The application of plant growth regulators significantly influenced the vegetative parameters of pot anthurium (Table 2). The plant height in different treatments varied from 15.6 cm to 21.0 cm. The maximum height of 21.0 cm was achieved with plants treated with GA3 @ 500 ppm and the minimum plant height observed with CCC@ 500 ppm (15.6 cm). The significant increase in plant height observed with GA3 application due to the effective action of gibberellins, which promote vegetative growth through cell division and elongation (Ara *et al.,* 2022). This likely resulted in the enhanced plant height. Additionally, GA₃ promotes photosynthetic activity, likely aiding in the osmotic absorption of water and nutrients by sustaining stable turgor pressure, which counters the softening of cell walls (Jayashree *et al.* 2020).

The number of leaves per plant showed significant differences among treatments. Maximum number of leaves (23.0) was recorded with BA @ 500 ppm, which was statistically at par with T5 (21.8) and T11 (20.6). The lowest leaf count (16.0) was observed with CCC @ 500 ppm. Sucker production per plant was also significantly affected by the treatments. Plants treated with 500 ppm BA produced the highest number of suckers (3.8) and control had the least number of suckers (0.6). Application of Benzyl adenine may have caused the plant to produce the highest number of leaves possibly by stimulating the leaf primordial in the apical growing region. This effect aligns closely with the findings of Ragini *et al.* (2019).

Leaf dimensions (length and breadth) were also significantly enhanced by the growth regulators. The maximum leaf length (7.38 cm) and breadth (3.26 cm) were observed in plants treated with GA3 @ 500 ppm, statistically similar to those treated with BA @ 500 ppm, GA3 @ 400 ppm, and BA @ 400 ppm. The increase in cell division rate and the induction of bud break in both aerial and subterranean parts of the plant may be attributed to the effect of cytokinins. This phenomenon can be explained by the release of apical dominance due to the application of a higher concentration of cytokinin (BA), which alters the auxin to cytokinin ratio. The inhibitory effect of BA on auxin synthesis indirectly facilitates the production of lateral shoots, as reported by other scientists on anthurium (Seemanthini and Chandrashekar, 2018).

Further, plant spread in both directions (East-West and North-South) was highest in plants treated with BA @ 500 ppm, with dimensions of 21.32 cm and 23.2 cm, respectively. These results were statistically comparable to plants treated with BA @ 400 ppm and GA3 @ 500 ppm. Such increase in plant spread in both directions (E-W and N-S) is likely due to enhanced cell division and elongation, as well as the production of a higher number of lateral branches. This ultimately led to an improved plant spread and an increased number of leaves per branch. Gibberellin plays a major role in regulating various physiological process in plant tissue (Sharma and Zheng, 2019). Thakur *et al.*  (2023) also explained that gibberellins have a very prominent role in increasing plant growth and development and also adaptation to environmental conditions.

**Table 2. Effect of plant growth regulators on vegetative parameters of pot Anthurium**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | | **Vegetative parameters** | | | | | | |
| **Plant height (cm)\*** | **Number of leaves per plant\*** | **Number of suckers per plant\*** | **Leaf length (cm)\*** | **Leaf breadth**  **(cm)\*** | **Plant spread**  **(E-W)**  **(cm)\*** | **Plant spread**  **(N-S)**  **(cm)\*** |
| T1 | Control | 17.6 | 17.4 | 0.6 | 6.22 | 2.6 | 17.24 | 19 |
| T2 | BA@100 ppm | 18 | 19.2 | 1.8 | 6.36 | 2.66 | 18.4 | 20.4 |
| T3 | BA@200 ppm | 18.4 | 19.8 | 2.4 | 6.54 | 2.74 | 18.6 | 21 |
| T4 | BA@300 ppm | 18.8 | 20.2 | 2.6 | 6.6 | 2.7 | 19.34 | 21.4 |
| T5 | BA@400 ppm | 19 | 21.8 | 3.2 | 6.64 | 2.88 | 20.3 | 22 |
| T6 | BA@500 ppm | 19.2 | **23** | **3.8** | 6.92 | 2.94 | **21.32** | **23.2** |
| T7 | GA3@100 ppm | 18.6 | 17.8 | 1.6 | 6.4 | 2.46 | 17.4 | 19.2 |
| T8 | GA3@200 ppm | 18.8 | 18 | 1.8 | 6.58 | 2.58 | 17.6 | 19.24 |
| T9 | GA3@300 ppm | 19.4 | 18.4 | 2.2 | 6.62 | 2.8 | 18 | 19.44 |
| T10 | GA3@400 ppm | 20.4 | 18.6 | 2.6 | 6.86 | 2.92 | 19.8 | 20.2 |
| T11 | GA3@500 ppm | **21** | 20.6 | 3 | **7.38** | **3.26** | 20 | 21.4 |
| T12 | CCC@100 ppm | 17 | 17.4 | 0.8 | 6.18 | 2.6 | 17.6 | 19.4 |
| T13 | CCC@200 ppm | 16.6 | 17 | 1 | 6.14 | 2.58 | 17.7 | 19.6 |
| T14 | CCC@300 ppm | 16.4 | 16.6 | 1.2 | 5.9 | 2.3 | 18.1 | 20.08 |
| T15 | CCC@400 ppm | 16 | 16.4 | 1.4 | 5.76 | 2.32 | 18.2 | 20.16 |
| T16 | CCC@500 ppm | 15.6 | 16 | 1.6 | 5.42 | 2.2 | 18.6 | 20.3 |
|  | SEm (±) | **0.71** | **0.90** | **0.31** | **0.27** | **0.19** | **0.70** | **0.78** |
|  | CD 5% | **2.00** | **2.53** | **0.87** | **0.75** | **0.53** | **1.99** | **2.20** |

**\*Significant at 5%**

Note: T: Treatment; BA: Benzyl adenine; GA3: Gibberellic acid; CCC: Cycocel; ppm: Parts Per Million

The effect of growth regulators on flowering parameters of pot anthurium were also found significantly different across various parameters. For instance, the number of flowers per plant exhibited considerable variation among treatments (Table 3). Notably, plants treated with GA3 @ 500 ppm produced the highest number of flowers per plant (3.2), statistically at par with plant treated with BA @ 500 ppm (2.8) and GA3 @ 400 ppm (2.6). Whereas, untreated plants displayed the lowest flower count per plant (0.8). Pot anthurium treated with GA3 @ 500 ppm produce the highest number of flowers, likely because GA3 stimulates the rapid growth of auxiliary buds and promotes flowering. This enhanced bud development is a key factor in the increased flower production per plant. (Kumar *et al.*, 2019). The increase in the number of flowers observed with GA3 @ 500 ppm can also be attributed to several key effects of the hormone. This treatment led to elevated levels of chlorophyll and protein in the leaves, while also significantly reducing the activity of chlorophyllase enzymes. By inhibiting chlorophyllase, GA3 prevented the degradation of chlorophyll and proteins, thereby enhancing the rate of photosynthesis. As a result, photosynthates were more effectively directed towards reproductive structures, leading to a highest number of flowers per plant (Morris, 2017).

Further, spadix length and breadth were significantly influenced by the application of growth regulators. Treatment with GA3 @ 500 ppm notably enhanced spadix length to 1.38 cm and breadth to 0.36 cm (Table 3). Similarly, marked differences were observed in spathe length and breadth among treatments. The highest spathe length and breadth were recorded in plants treated with GA3 @ 500 ppm i.e. 4.46 cm and 2.82 cm, followed by GA3 @ 400 ppm and BA @ 500 ppm. In contrast, untreated plants exhibited the minimum spathe dimensions. Increase in spadix length and breadth may be attributed to favourable conditions near the root zone, which facilitate increased nutrient and water uptake, thereby improving the supply of photosynthates to the developing sinks. These results are in consistent with the findings of previous studies conducted on anthurium plants (Anjali *et al.,* 2013). The enhancement of spathe size attributed to GA3 can be traced to its role in promoting the efficient translocation of metabolites to the spathe development site. Gibberellic acid (GA3) likely triggers a complex developmental process by activating regulatory genes during the later stages of corolla formation, as documented in studies on anthurium. This activation fosters increased spathe length and breadth through heightened cell division and elongation in the flowers, thus strengthening the sink capacity of these growing structure (Muraleedharan *et al*., 2018; Chandel *et al.*, 2023). The spathe colour was red (46 A) as per RHS colour chart, irrespective of treatments. It was observed that the color of the flowers remains unchanged even after the application of various plant growth regulators. This phenomenon has also been observed by Beena (2000) in Anthurium plants.

**Table 3. Effect of plant growth regulators on flowering parameters of pot Anthurium**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | | **Flowering parameters** | | | | | |
| **Number of flowers per plant\*** | **Spadix length (cm)\*** | **Spadix breadth**  **(cm)\*** | **Spathe length**  **(cm)\*** | **Spathe breadth**  **(cm)\*** | **Spathe**  **Colour\*\*** |
| T1 | Control | 0.8 | 0.86 | 0.18 | 2.92 | 2.1 | Red (46A) |
| T2 | BA@100 ppm | 1.4 | 1.06 | 0.22 | 3.12 | 2.24 | Red (46A) |
| T3 | BA@200 ppm | 1.8 | 1.14 | 0.24 | 3.2 | 2.28 | Red (46A) |
| T4 | BA@300 ppm | 2 | 1.16 | 0.26 | 3.22 | 2.3 | Red (46A) |
| T5 | BA@400 ppm | 2.4 | 1.24 | 0.28 | 3.44 | 2.42 | Red (46A) |
| T6 | BA@500 ppm | 2.8 | 1.32 | 0.32 | 3.74 | 2.56 | Red (46A) |
| T7 | GA3@100 ppm | 2 | 1.12 | 0.24 | 3.36 | 2.18 | Red (46A) |
| T8 | GA3@200 ppm | 2.2 | 1.18 | 0.26 | 3.66 | 2.36 | Red (46A) |
| T9 | GA3@300 ppm | 2.4 | 1.24 | 0.28 | 3.84 | 2.38 | Red (46A) |
| T10 | GA3@400 ppm | 2.6 | 1.3 | 0.32 | 4.06 | 2.54 | Red (46A) |
| T11 | GA3@500 ppm | **3.2** | **1.38** | **0.36** | **4.46** | **2.82** | Red (46A) |
| T12 | CCC@100 ppm | 1 | 1.12 | 0.28 | 3.56 | 2.48 | Red (46A) |
| T13 | CCC@200 ppm | 1.2 | 1.06 | 0.26 | 3.22 | 2.4 | Red (46A) |
| T14 | CCC@300 ppm | 1.8 | 1.06 | 0.24 | 3.12 | 2.32 | Red (46A) |
| T15 | CCC@400 ppm | 2 | 1 | 0.22 | 3.18 | 2.3 | Red (46A) |
| T16 | CCC@500 ppm | 2.2 | 0.88 | 0.2 | 2.96 | 2.2 | Red (46A) |
|  | SEM (±) | **0.23** | **0.06** | **0.03** | **0.21** | **0.11** |  |
|  | CD 5% | **0.66** | **0.16** | **0.10** | **0.60** | **0.31** |  |

**\*Significant at 5%**

**\*\*Colour of spathe was measured using RHS colour chart**

Note: T: Treatment; BA: Benzyl adenine; GA3: Gibberellic acid; CCC: Cycocel; ppm: Parts Per Million

1. **CONCLUSION**

The present study, indicated that applying GA3 @ 500ppm and BA @ 500ppm resulted in superior performance in terms of vegetative growth, flowering habit, quality, and flower yield . Pot-anthurium cultivation promises flower growers increased revenue; highly educated but unemployed youth can proudly engage themselves in the cultivation of this high-value flower, thus elevating their socio-economic status. Pot-anthurium is more than just a flower; it's an opportunity, a symbol of elegance, and a source of prosperity for our region's agricultural landscape. This research leads the way for entrepreneurs to venture into this wealthy crop.

**Declaration**

The authors declare that there is no conflict of interest.

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**REFERENCES**

Anjali, K. B., Akshay, K. R., & Sudharani, N. (2014). Evaluation and studies on effect of gibberellic acid on growth and yield of anthurium.

Ara, K. A., Kabir, K., Rashid, M. T., Sharifuzzaman, S. M., & Sadia, M. A. (2022). Influence of foliar application of growth regulators on vegetative growth and flowering of chrysanthemum. *Bangladesh Journal*, 69.

Beena, R. (2000). *Effect of growth regulators on the growth and flowering of anthurium (Anthurium andreanum Linden)* (Doctoral dissertation, Department of Plant Physiology, College of Agriculture, Vellayani).

Chandel, A., Thakur, M., Rakwal, A., Chauhan, S., & Bhargava, B. (2023). Exogenous applications of gibberellic acid modulate the growth, flowering and longevity of calla lily. *Heliyon*, 9.

Davies, P. J. (Ed.). (2004). *Plant hormones: biosynthesis, signal transduction, action!*. Springer Science & Business Media.

Gabrel, F., Mahmoud, K., & Ali El, N. (2018). Effect of benzyl adenine and gibberellic acid on the vegetative growth and flowering of chrysanthemum plant. *Alexandria Journal of Agricultural Sciences*, 63, 29–40.

Gomez, K. A. (1984). *Statistical procedures for agricultural research*. John Wiley and Sons, New York.

Jayashree, N., Chandrashekar, S. Y., Hemla Naik, B., Hanumantharaya, L., & Ganapathi, M. (2020). Influence of benzyl adenine and gibberellic acid on morphological behaviour of Asiatic lily. *International Journal of Chemical Studies*, 8, 2028–2031.

Kumar, M., Malik, S., Singh, M. K., Singh, S. P., Chaudhary, V., & Sharma, V. R. (2019). Optimization of spacing, doses of Vermi-compost and foliar application of salicylic acid on growth, flowering and soil health of chrysanthemum (*Dendranthema grandiflora* Tzvelev) cv. “Guldasta”. *International Journal of Agriculture, Environment and Biotechnology*, 12, 213–224.

Morris, D. A. (2017). Hormonal regulation of source-sink relationships: an overview of potential control mechanisms. In *Photoassimilate Distribution in Plants and Crops: Source-Sink Relationships* (pp. 441–466).

Muraleedharan, A., Kumar, R. S., Kousika, S., & Joshi, J. L. (2018). Growth and flowering on anthurium (*Anthurium andreanum* cv. Tropical) plants treated with foliar application of growth regulators. *Journal of Emerging Technologies and Innovative Research*, 5.

Muraleedharan, A., Sha, K., Kumar, S., Sujin, G. S., Joshi, J. L., & Kumar, C. P. (2020). Influence of seaweed extract along with growth regulators on the growth, flowering and yield of anthurium plants. *Plant Archives*, 20, 1196–1199.

Palei, S., Das, A. K., & Dash, D. K. (2016). Effect of plant growth regulators on growth, flowering and yield attributes of African marigold (*Tagetes erecta* L.).

Ragini, B. K., Chandrashekar, S. Y., Hemla, N. B., Shivaprasad, M., & Ganapathi, M. (2019). Effect of cytokinins (benzyl adenine and kinetin) on bulbous flower crops: A review. *International Journal of Chemical Studies*, 7, 2618–2622.

Seemanthini, N. S., & Chandrashekar, S. Y. (2018). A study on yield and economics of growth regulators application in *Anthurium andreanum* var. Tropical under naturally ventilated polyhouse. *International Journal of Pure and Applied Bioscience*, 6, 314–318.

Sharma, A., & Zheng, B. (2019). Molecular responses during plant grafting and its regulation by auxins, cytokinins, and gibberellins. *Biomolecules*, 9, 397.

Shudo, K. (2019). Chemistry of phenylurea cytokinins. In *Cytokinins* (pp. 35–42). CRC Press.

Singh, J., Nigam, R., Singh, R., Kumar, A., & Kumar, A. (2018). Effect of gibberellic acid and cycocel on growth, flowering and yield of chrysanthemum (*Dendranthema grandiflora* Ramat) cv. Birbal Sahni. *Journal of Pharmacognosy and Phytochemistry*, 7, 2753–2758.

Thakur, R., Chandermohan, N. C., & Kanwar, B. (2023). Effect of gibberellic acid and benzyl adenine on ornamental plants: A review.

Yadav, B., Jogawat, A., Rahman, M. S., & Narayan, O. P. (2021). Secondary metabolites in the drought stress tolerance of crop plants: A review. *Gene Reports*, 23, 101040.