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Effect of Foliar Application of Gibberellic acid and Salicylic Acid on the Growth, Physiology and Anatomy of *Celosia cristata* L.

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ABSTRACT

Cockscomb is an ornamental plant that withstands moderate temperature and moisture during the summer season. The aim of this study is to investigate how plant growth regulators can alleviate stunted growth and flower head drop in celosia, a common issue affecting its development. This study checked the effect of foliar application of GA_3 and SA on Celosia. Different concentrations of GA_3 50 mgL^{-1}, 100 mgL^{-1}, 150 mgL^{-1} and SA of 50 mgL^{-1}, 100 mgL^{-1}, and 150 mgL^{-1} was used. There was total seven treatments and each treatments was replicated three times. Complete Randomized Design was used to organize the experiment. Data was collected for different morphological parameters, physiological and anatomical parameters. Recorded data showed that T_2 GA_3 (100 mg/l) showed maximum plant height (99.66 cm), number of leaves (89.66 count), plant stem diameter (28.10 cm), leaf area (29.5 cm^2), fresh mass of flower (101.93 g), dry mass of flower (97.55 g), flower quality (9), total chlorophyll content (23.93), SOD (1.05), POD (0.41), abaxial stomata density (2015.3 μm^2), adaxial stomata density (2914 μm^2), lamina thickness (296.84 µm), lamina thickness (656.32 μm^2), adaxial stomatal area (456.63 μm^2), abaxial stomatal area (530.4 μm^2), number of vascular bundles (36.66 count), phloem area (275.51 μm^2), and meta xylem area (623.93 μm^2) as compared to all other treatments. It is concluded that that GA3 foliar spraying is an effective approach to enhance the quality and productivity of Celosia.

Keywords: celosia, gibberellic acid, salicylic acid

Introduction:

Celosia cristata is a decorative plant belonging to the *Amaranthaceae* family, native of Mexico, North America, tropical Africa, West India, and Southeast Asia (Rehana and Bala, 2022). Celosia, known as cockscomb, thrives in warm climates with ample sunlight and well-drained soil. It grows sturdy stems bearing vibrant, crested flower heads (Zuck, 2015). These plants can grow in various conditions, but they thrive best in warm climates with well-draining soil and plenty of sunlight (Montgomery, 2021). *Celosia cristata* holds significant medicinal value. (Islam et al., 2016).

Celosia is commonly called Cockscomb because of its resemblance to rooster-head. The occurrence of the rooster-head phenotype is primarily triggered by the presence of gibberellins which has earned it the informal nickname cockscomb due to its striking likeness during its developmental phases (Shanan et al., 2014). Plant growth regulators are commonly employed to inhibit stem extension and promote a more compact plant architecture (Trivellini et al., 2023). To attain economic feasibility, the use of growth regulators becomes imperative for the purpose of regulating plant stature and facilitating the growth of well-branched, condensed, robust, and abundant-flowering plants (Hossain et al., 2022).

Gibberellins have various types, among which gibberellic acid and salicylic acid are significant and extensively utilized active forms in the field of agriculture. Gibberellins are recognized to be important plant developmental processes (Bhatt, 2020).These include the stimulation of seed germination, initiation of the transition from meristem to shoot growth, facilitation of the shift from the juvenile to the adult leaf stage, promotion of the transition from vegetative to flowering phases, influence on sex expression, and contribution to grain formation (Vishal and Kumar, 2018). The plant growth regulators, when used properly, can restrict plant growth without side effects (Guo et al., 2011).

Gibberellic acids (GAs) are a type of diterpenoid compound belonging to gibberellin group of plant hormones. Gibberellic acid has a substantial role in influencing various aspects of plant growth, differentiation, and development, especially when present in low quantities. The main effect of gibberellins is the stimulation of stem hyper-elongation through the promotion of cell division, elongation and the enhancement of flower bud development (Shanan et al., 2014). When plants face conditions that inhibit normal growth, applying GA_3 can stimulate stunted growth by promoting cell elongation and division in stems. This is particularly beneficial in overcoming growth which could indirectly contribute to addressing issues related to overall development of stunted plants (Bhatt, 2020).

Salicylic acid (SA) functions as a vital endogenous signaling molecule, augmenting the plant's ability to endure salt stress through the regulation of growth and physiological mechanisms (Shoaib et al., 2021). Salicylic acid has an important role in improving the efficiency of photosynthesis by increasing transpiration rates, stomatal conductance levels, and enzyme activity related to CO_2 absorption at the chloroplast level (Janda et al., 2014). SA contributes to the plant's ability to defend itself against diseases and stress, which could indirectly help prevent issues like dropping of leaves and flower heads.

Salicylic acid (SA), a phenolic compound naturally synthesized by plant roots, emerges as a critical player in plant growth. This endogenous hormone acts as a master modulator, influencing a wide range of metabolic and physiological processes within the plant. SA significantly impacts plant (Huang et al., 2021).

Celosia cristata is often challenged by various environmental stresses including sunburn, stunted growth and premature dropping of flower heads. These factors not only compromise the aesthetic appeal of the plant but also affect its overall health and vigor (Irshad et al., 2022). This research explores the effects of foliar applied gibberellic acid and salicylic acid on the growth, physiological characteristics and anatomical features of Celosia cristata. Different concentrations of these plant growth regulators will be investigated.

MATERIAL AND METHOD

This study was conducted at Lalazar Plant Nursery Area, Gardening Wing, University of Agriculture Faisalabad under Completely Randomized Design (CRD). Seeds of *Celosia cristata* L. were purchased from Chanin Din Seeds. Seeds were sown in a plug tray to prepare the seedlings of Celosia

during the month of March (2023-2024). When seedlings reached 3-4 leaf stages, they were shifted to 12-inch pots containing an equal proportion of leaf compost and silt. Each treatment was replicated thrice, and each replication consisted of three plants. Cultural practices like weeding, hoeing and irrigation were performed under following treatments T_0= Water, T_1= Gibberellic acid (50 mg L^{-1}), T_2= Gibberellin acid (100 mg L^{-1}), T_3= Gibberellic acid (150 mg $L^{-1)}$, T_4= Salicylic acid (50 mg L^{-1}), T_5= Salicylic acid (100 mg L^{-1}), T_6= Salicylic acid (150 mg L^{-1})

Experimental data was recorded on the following parameters of plants:

Morphological attributes

The plant height was measured by using vernier caliper in and readings were noted daily. The total number of leaves on each plant was counted daily and the average was calculated. For leaf area that leaves taken were fully mature taken from lower, middle, and upper sides of plant in each replication, their maximum length and breadth of leaf was calculated with meter rod and leaf area was premeditated by using the method described by (Chaudhary et al., 2012).

Leaf area (cm^2) = Length x Maximum breadth x 0.68

Where 0.68 constant factor.

The stem diameter of selected plants per replication was recorded using digital caliper from just below the first leaf emerging point and averages were calculated. Flower quality was measured on the scale ranging from 1 to 10 (1 for bad quality and 10 for best quality). It was calculated by checking the flower with three judges. Fresh flowers were taken from each replication and weight was calculated by placing flower on weighing balance and readings were noted. After fresh mass was taken, flowers were sun dried for seven days. Later, dry mass was taken by weighing balance and readings were noted.

Photosynthetic pigments

A chlorophyll meter was used to measure leaf chlorophyll content. Leaves were placed on chlorophyll meter to take the reading and average chlorophyll content was noted.

Biochemical attributes

SOD activity was calculated using a quartz cuvette in which required solutions were added in an appropriate order, First, 400 ul distilled water was poured in the plastic cuvettes that were followed by addition of 250 µl potassium phosphate buffer, 100 µl of L-methionine solution, 100 µl from solution of Triton X, 50 µl of NBT Solution, 50 µl of leaf extracted sample and at the end add 50 µl of riboflavin. Place all the cuvettes under a light lamp for almost 15-20 minutes to start the reaction. After 15 minutes, ran a blank sample noted the readings at 560 mm and then absorbance by all the samples was also recorded (Zhang et al., 2016). Method of measuring the POD activity was followed in cuvette, 750 µl of phosphate buffer, 100 µl guaiacol, 50 µl of plant leaf extract and 100 ul of H_2O, in a regular manner was added each time. The absorbance was recorded after every 30 seconds at 470 nm (Wang et al., 2012).

3.3 Methodology of leaf Anatomy

Leaf samples were collected from each treatment and the leaves were preserved in 70% alcohol for further usage. The plant material which was required for anatomical purposes such as root was separated from plants with the help of sharp razor blade and preserve them in 70% alcohol in plastic bottles. After this label the bottles along with plant names. Free hand sectioning techniques were used for the preparation of permanent slides of transverse sections of leaf. Potato tubers were used for sectioning leaves. Picked up the sample from 70% alcohol with the help of forceps and fixed it in potato tubers. Cut the transverse sections of potato tubers with the help of sharp razor blade and put them in petri dish and add some drops of water to avoid dehydration. Then select the fine thin sections of sample and transfer from petri plates to watch glass with the help of needle for staining.

Sections were differentiated to get different types of tissues. In this procedure of leaf anatomy, first, sections were stained in 30% alcohol for 15 minutes then wiped with tissue paper. Then, these sections were stained with 50% alcohol for 15 minutes then 50% alcohol was also removed with tissue paper, moreover, these sections were stained with 70% alcohol, and after 15 minutes, 70% alcohol was also removed with the help of tissue paper. Meanwhile, a few drops of safranin were added in watch glass for 10-15 minutes for staining. After removing 70% alcohol concentration, 90% alcohol was added for 5 minutes, and only 1 drop of quick green was put to the watch glass for a few seconds before being rinsed with 100% alcohol 2-3 times. At the end xylene was added in watch glass for few seconds. After three seconds, xylene was removed from the sections and sections were carefully moved from watch glass to final slide. While preparing the final slide, 3 drops of canada balsam was dropped on the tissues to avoid air penetration and making bubbles in tissues. Then, tissues were covered with cover slip. After, microscopic photos were taken, and different parameters were studied as showed in Fig .5.

Complete Randomized Design (CRD) was followed for the layout of experiment having three replications and three plants within each replication. All the Data observed was statistically analyzed by using the analysis of variance ANOVA technique according to Fisher's technique of analysis to determine the significance parameters and treatment means were compared according to least significance difference test (LSD) at probability value 5% (Steel et al., 1997).

Results

Morphological Attributes

Mean square values of ANOVA indicated that foliar application of GA_3 an SA considerably improved the morphological attributes of Celosia cristata. The individual effect of different foliar treatments was significant for the morphological parameters. The maximum plant height was obtained from T_2 (99.66 cm) followed by T_5 (93.66 cm) and T_6 (76.66 cm). Respectively, T_3 (74.66 cm), T_4 (56.00 cm), and T_1 (52.66 cm) showed minimum plant height. However, T_0 (control) showed lowest plant height of (45.00 cm). The maximum number of leaves was obtained from T_2 (89.66 count) followed by T_5 (82.66 count), T_6 (66.33 count). Respectively, T_3 (65.33 count), T_4 (48.66 count), T_1 and (47.33 count) showed the minimum number of leaves. While T_0 showed the lowest number of leaves (36.33 count). The maximum plant stem diameter was shown in T_2 (28.10 cm) followed by T_5 (21.87 cm) and T_3 (19.36 cm). Respectively, T_6 (17.58 cm), T_1 (13.87 cm), and T_4 (13.76 cm) showed minimum plant stem diameter. However, T_0 showed the lowest plant stem diameter (10.59 cm). The maximum leaf area was shown in T_2 (29.5 cm^2) followed by T_3 (25.13 cm^2)

and (23.26 cm^2). Respectively, T_5 (21.36 cm^2), T_1 (21.2cm^2) and T_4 (18.96 cm^2) showed minimum leaf area. However, T_0 showed the lowest leaf area (16.96 cm^2). The maximum fresh mass of flower was obtained from T_2 (101.93 g) followed by T_3 (86.55 g) and T_6 (75.81 g). Respectively, T_5 (69.33 g), T_1 (36.09 g), and T_4 (32.28 g) showed minimum fresh mass of flower. However, T_0 showed the lowest fresh mass of flower (20.23 g). The maximum flower dry mass was obtained in T_2 (97.55 g) followed by T_6 (77.70 g) and T_5 (71.11 g). Respectively, T_3 (64.09 g), T_1 (30.36 g), and T_4 (28.99 g) showed minimum dry mass of flower. However, T_0 showed the lowest dry mass of flower (15.32 g). The highest flower quality was obtained in T_2 (9) followed by T_6 (8.33) and T_5 (7.33). While T_3 (7.33), T_1 (4.42), and T_4 (3.66) showed minimum flower quality. However, T_0 showed the lowest flower quality (3.5) (Table 1.).

Photosynthetic pigments

Photosynthetic pigments such as total chlorophyll contents were significantly increased in T_2 (23.93 SPAD) followed by T_5 (22.1 SPAD) and T_6 (17.13). While T_3 (15.3 SPAD), T_1 (14 SPAD) and T_4 (10.73 SPAD) showed minimum total chlorophyll content. However, T_0 showed the lowest total chlorophyll content (5.03 SPAD) (Fig 1.A).

Biochemical attributes

Data concerning SOD due to foliar application of GA_3 and SA on (*Celosia cristata* L) were analyzed statistically. The highest SOD activity was noted in T_2 (1.05) followed by T_3 (0.35) and (0.27). While T_6 (0.21), T_1 (0.16), and T_4 (0.10) showed minimum SOD. However, T_0 showed the lowest SOD (0.01) (Fig 1.B). The highest POD activity was shown in T_2 (0.41) followed by T_5 (0.4) and T_3 (0.31). While T_6 (0.23), T_4 (0.10), and T_1 (0.08) showed minimum POD. However, T_0 showed the lowest POD (0.01) (Fig 1.C).

Leaf Anatomy

Data concerning leaf anatomy obtained from the foliar application of GA_3 and SA on (*Celosia cristata* L.) were analyzed statistically. The maximum abaxial stomata density (μm^2) was obtained in T_2 (2015.3 μm^2) followed by T_3 (1634 μm^2) and T_5 (1252.7 μm^2). Respectively, T_6 (1225.5 μm^2), T_1 (925.9 μm^2), and T_4 (653.6 μm^2) showed minimum abaxial stomata density. However, T_0 showed the lowest abaxial stomata density (326.8 μm^2) (Fig 2.A). The maximum adaxial stomata density was obtained in T_2 (35.66 count) followed by T_5 (22.00 count) and T_3 (22.00 count). Respectively, T_6 (18.66 count), T_4 (17.00 count), and T_1 (14.66 count) showed minimum adaxial stomata density. However, T_0 showed the lowest adaxial stomata density (8.00 count) (Fig 2.B). The maximum lamina thickness was observed in T_2 (296.84 µm) followed by T_5 (228.76 µm) and T_6 (179.74 µm). Respectively, T_3 (125.27 µm), T_4 (117.1 µm), and T_1 (62.64 µm) showed minimum lamina thickness. However, T_0 showed the least lamina thickness (29.62 µm) (Fig 2.C). The maximum abaxial stomatal area was shown in T_2 (530.4 μm^2) followed by T_6 (268.17 μm^2) and T_3 (162.41 μm^2). While T_5 (109.26 μm^2), T_1 (56.99 μm^2), and T_4 (51.75 μm^2) showed minimum abaxial stomatal area. However, T_0 showed the lowest abaxial stomatal area (15.03 μm^2) (Fig 3.D).

The maximum midrib thickness was observed in T_2 (656.32 μm^2) followed by T_3 (550.11 μm^2) and T_5 (514.71 μm^2). While T_6 (460.46 μm^2), T_1 (430.29 μm^2), and T_4 (424.84 µm) showed minimum midrib thickness. However, T_0 showed the lowest midrib thickness (364.93 μm^2) (Fig 3.E). The maximum adaxial stomatal area was observed in T_2 (456.63 μm^2) followed by T_5 (301.91 μm^2) and T_3 (242.65 μm^2). Respectively, T_6 (198.94 μm^2), T_4 (82.51 μm^2), and T_1 (48.6 μm^2) showed minimum adaxial stomatal area. However, T_0 showed the lowest adaxial stomatal area (5.42 μm^2) (Fig 3.F). The highest number of vascular

bundles was observed in T_2 (36.66 count) followed by T_5 (30.66 count) and T_3 (26.33 count). Respectively, T_6 (26.33 count), T_4 (20.66 count), and T_1 (14.66 count) showed the minimum number of vascular bundles. However, T_0 showed the lowest number of vascular bundles (6.66 count) (Fig 4.G). The maximum phloem area was observed in T_2 (441.24 μm^2) followed by T_5 (182.86 μm^2) and T_3 (145.1 μm^2). While T_6 (57.69 μm^2), T_1 (32.17 μm^2), and T_4 (14.68 μm^2) showed minimum phloem area. However, T_0 showed the lowest phloem area (12.94 μm^2) (Fig 4.H). The maximum meta xylem area was observed in T_2 (623.93 μm^2) followed by T_1 (532.32 μm^2), T_4 (174.82 μm^2). While T_6 (150.34), T_0 (110.83 μm^2), and T_5 (93.18 μm^2) showed minimum meta xylem area. However, T_3 showed the lowest meta xylem area (87.41 μm^2) (Fig 4.1).

Table 1. Effect of foliar application of GA_3 and SA on the morphological attributes of *Celosia cristata* L.

Treatments	Plant Height	Number of Leaves Per Plant	Plant Stem Diameter	Leaf Area	Fresh Mass of Flower	Flower Quality	Flower Dry Mass
T_0	45.00±1.1e	36.33±1.7e	10.59±0.3e	16.96± 0.3d	20.23±0.4f	3.5±0.2d	15.32±1.0f
T_1	52.66±1.7d	47.33±1.4d	13.84±0.7d	21.2±2.3c	36.09±1.7e	4.42±0.1c	30.36±1.6e
T_2	99.66±2.9a	89.66±2.9a	28.10±1.1a	29.5±0.5a	101.93±1.2a	9±0.1a	97.55±0.7a
T_3	74.66±2.0c	65.33±2.3c	19.36±0.9c	25.13±0.9b	86.55±2.1b	7.33±0.3b	64.09±1.6d
T_4	56.00±1.7d	48.66±1.4d	13.76± 0.6d	18.96±0.2d	32.28±0.7e	3.66±0.3cd	28.99±0.7e
T_5	93.66±1.4b	82.66±1.4b	21.88±0.7b	21.36±0.2c	75.81±1.8d	8.33±0.3a	71.11±1.4c
T_6	76.66±2.0c	66.33±2.6c	17.58±0.7c	23.26±0.4bc	86.55±1.8c	7.33±0.3b	77.70±3.8b

Values (mean ± standard error), LSD = least significant difference; Means separation within columns by Fisher's LSD at $P<0.05$. T_0= Water, T_1= Gibberellic acid (50 mgL^{-1}), T_2= Gibberellic acid (100 mgL^{-1}), T_3= Gibberellic acid (150 $mgL^{-1)}$, T_4= Salicylic acid (50 mgL^{-1}), T_5= Salicylic acid (100 mgL^{-1}), T_6= Salicylic acid (150 mgL^{-1})

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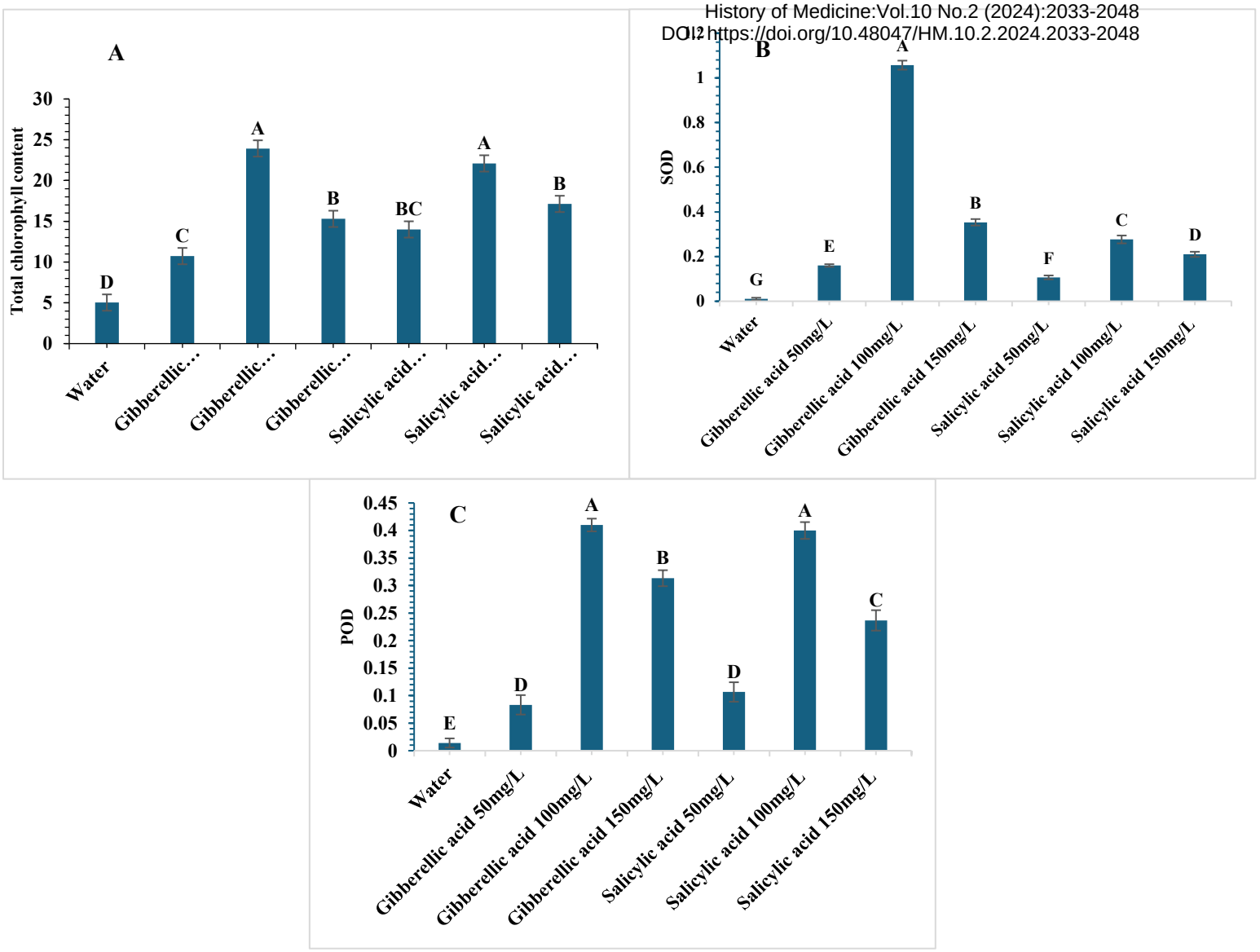

Fig 1. Effect of foliar application of GA_3 and SA on the total chlorophyll content (SPAD) (A), SOD (B) and POD (C) of *Celosia cristata* L. T_0= Water, T_1= Gibberellic acid (50 mgL^{-1}), T_2= Gibberellic acid (100 mgL^{-1}), T_3= Gibberellic acid (150 mgL^{-1}), T_4= Salicylic acid (50 mgL^{-1}), T_5= Salicylic acid (100 mgL^{-1}), T_6= Salicylic acid (150 mgL^{-1})

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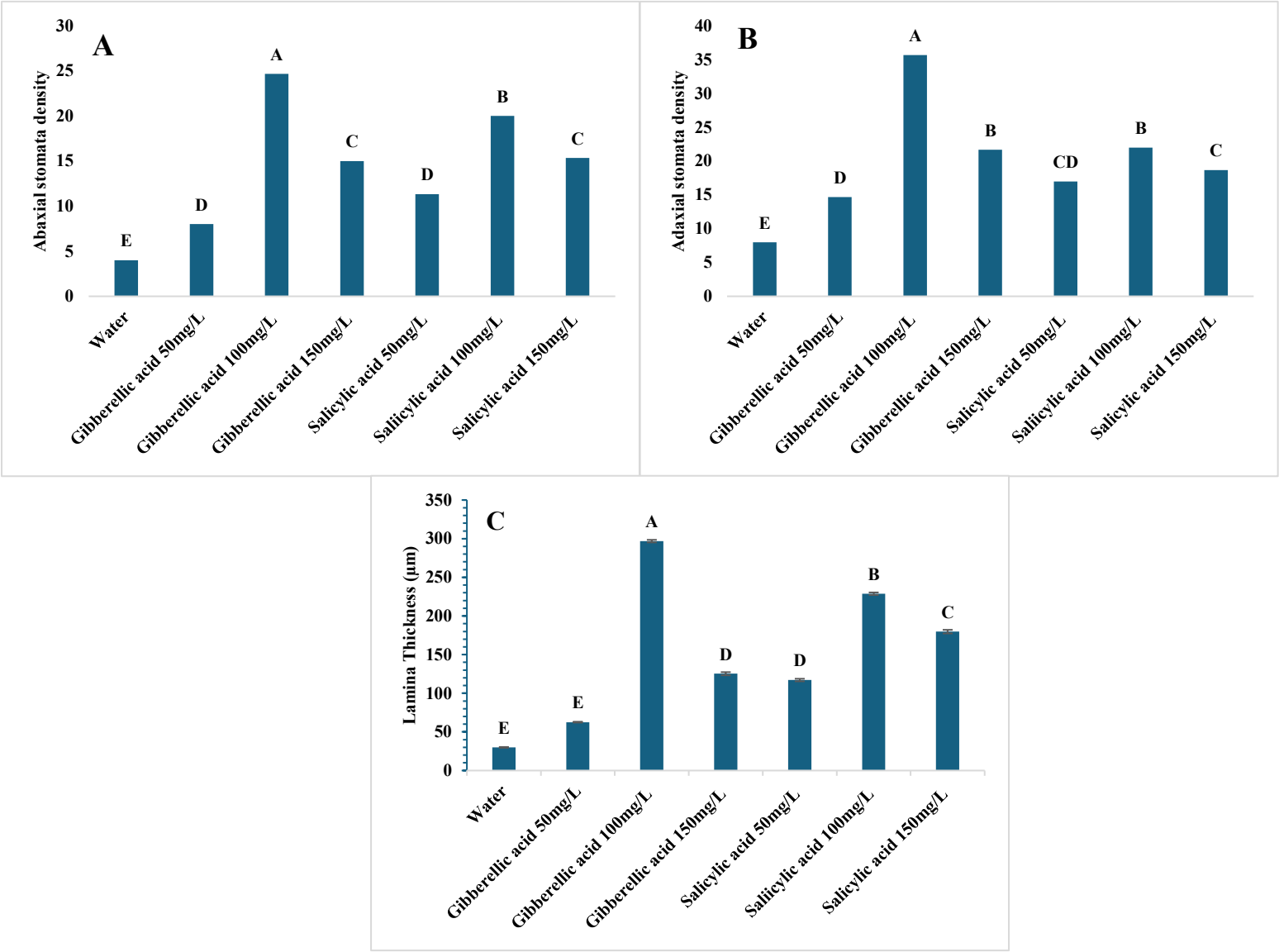

Fig 2. Effect of foliar application of GA_3 and SA on abaxial stomatal density (A), adaxial stomatal density (B) and lamina thickness (C) of *Celosia cristata* L. T_0= Water, T_1= Gibberellic acid (50 mgL^{-1}), T_2= Gibberellic acid (100 mgL^{-1}), T_3= Gibberellic acid (150 $mgL^{-1)}$, T_4= Salicylic acid (50 mgL^{-1}), T_5= Salicylic acid (100 mgL^{-1}), T_6= Salicylic acid (150 mgL^{-1})

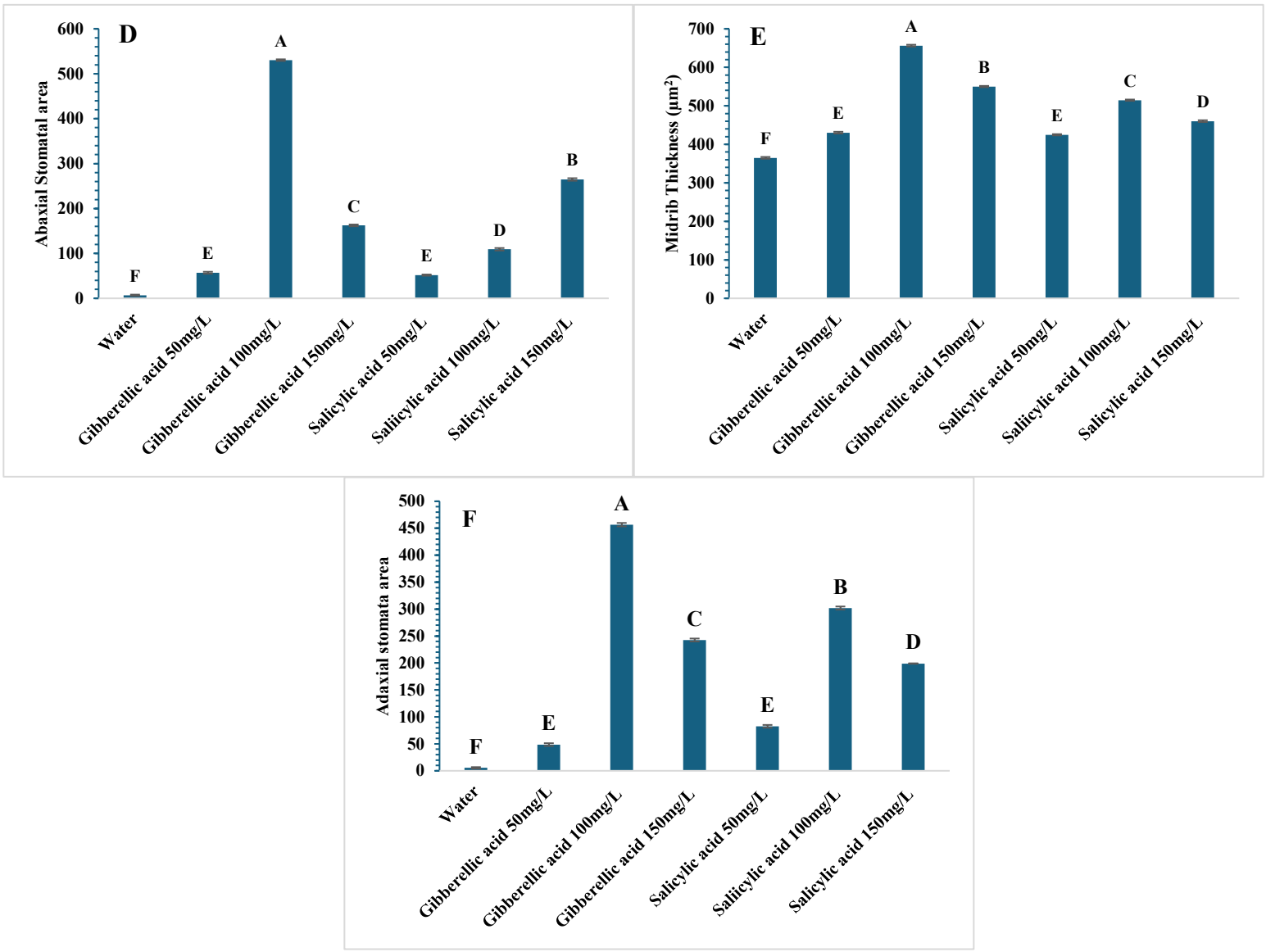

Fig 3. Effect of foliar application of GA_3 and SA on abaxial stomatal area (D), midrib thickness (E) and adaxial stomata area (F) of *Celosia cristata* L. T_0= Water, T_1= Gibberellic acid (50 mgL^{-1}), T_2= Gibberellic acid (100 mgL^{-1}), T_3= Gibberellic acid (150 mgL^{-1}), T_4= Salicylic acid (50 mgL^{-1}), T_5= Salicylic acid (100 mgL^{-1}), T_6= Salicylic acid (150 mgL^{-1})

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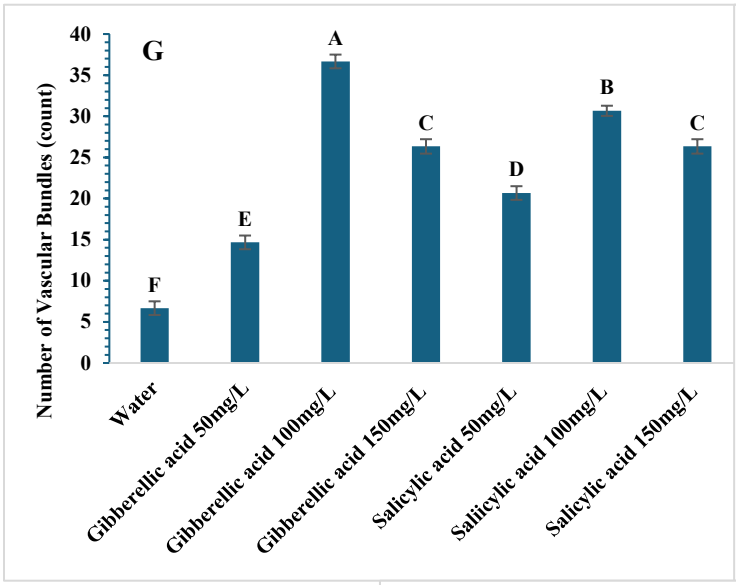

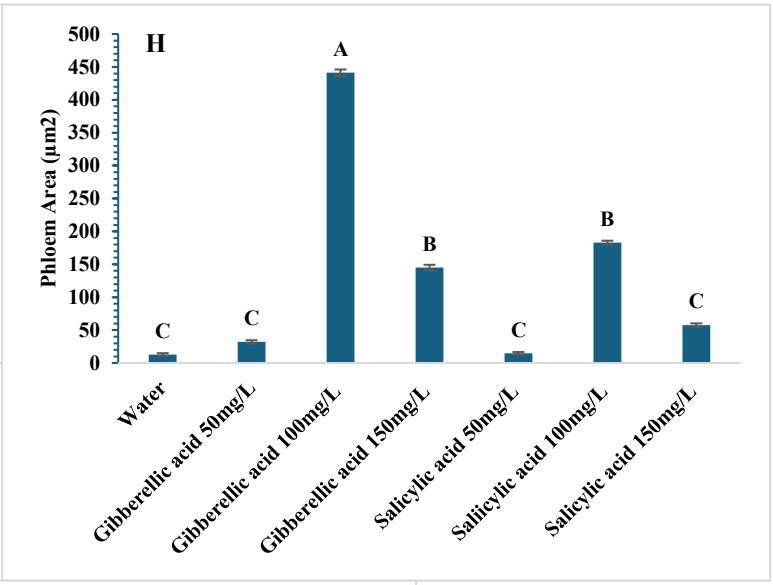

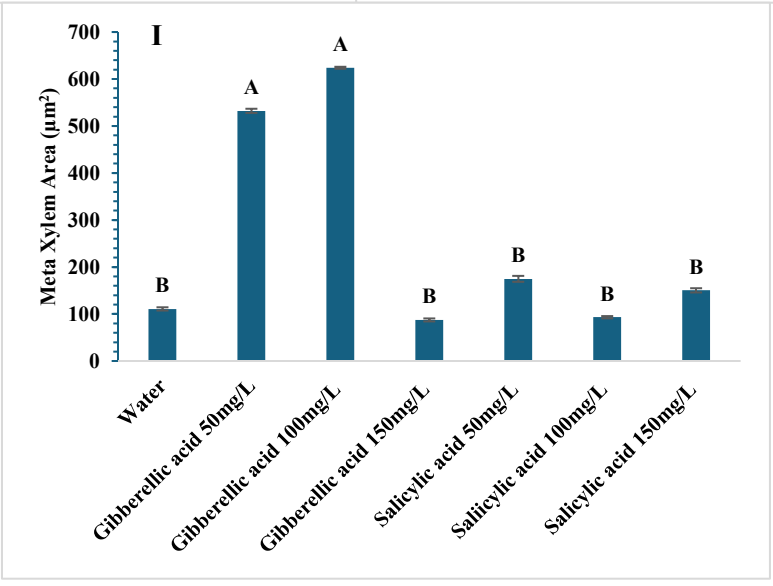

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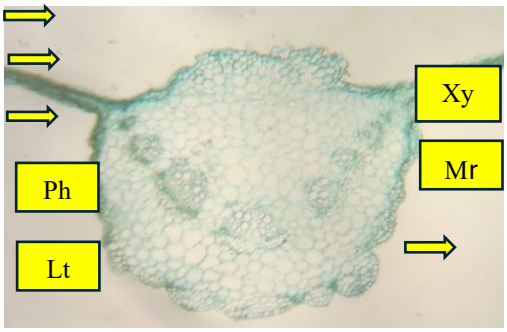
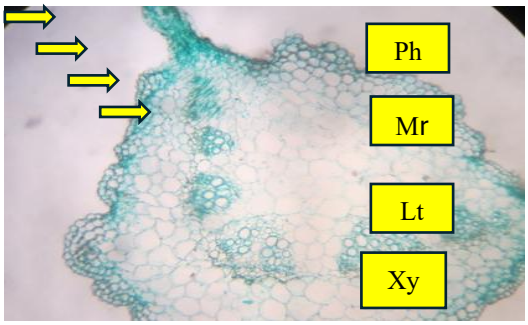
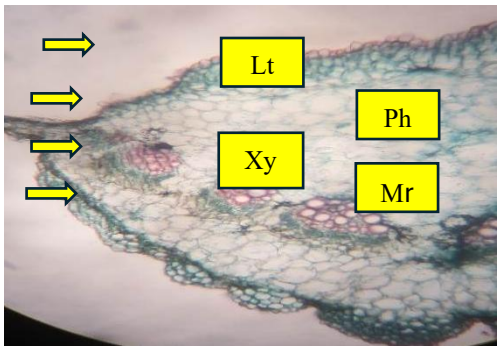
Fig 4. Effect of foliar application of GA_3 and SA on number of vascular bundles (count) (G) and phloem area (H) and meta xylem area (I) of *Celosia cristata* L. T_0= Water, T_1= Gibberellic acid (50 mgL^{-1}), T_2= Gibberellic acid (100 mgL^{-1}), T_3= Gibberellic acid (150 $mgL^{-1)}$, T_4= Salicylic acid (50 mgL^{-1}), T_5= Salicylic acid (100 mgL^{-1}), T_6= Salicylic acid (150 mgL^{-1})



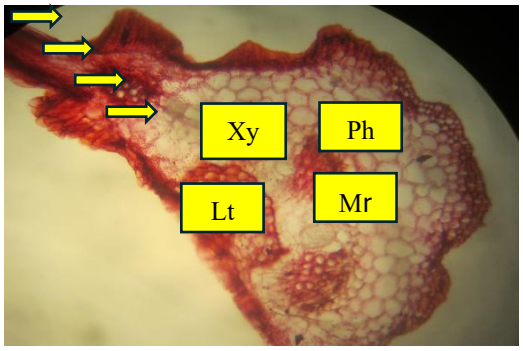
T_0



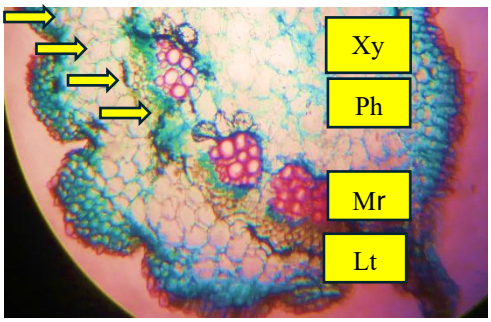
T_1

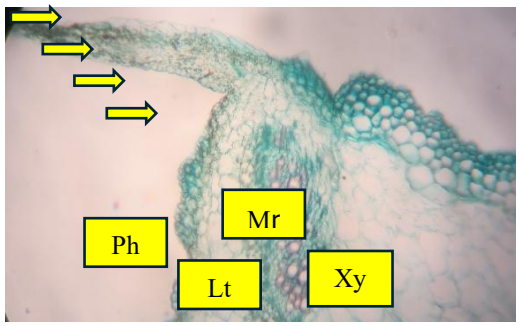


T_2



T_3





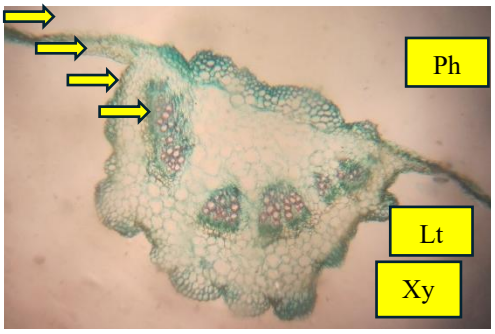
T_4 T_5

T_6

Fig.5 Leaf anatomical modification after effect of foliar application of GA_3 and SA on *Celosia cristata* L.]

Discussion

Biotic and abiotic factors hinder or lower the physiological attributes of ornamental plants. In *Celosia cristata* L. the dropping of flower heads and stunned growth is the most common problem that reduces the appearance of the plant. This present study was conducted to learn that how foliar application



of plant growth regulators effects the physiological attributes of cock's comb as spray of GA_3 significantly improved the plant height compared to control. The increase of plant height in *Celosia cristata* under the effects of gibberellic acid as compared to non-treated sample (Al-Chalabi, 2019). Treatment of GA_3 decreases the synthesis of ethylene, a plant hormone that prevents cell elongation and stimulates fruit maturation enabling the plant to allocate more energy towards vegetative growth and achieve greater height. Moreover, there is a potential increase in the characteristics of growth of *Celosia argentea* var. *cristata* L (Iqbal et al., 2020). The results showed that the GA_3 showed a significant increase in the growth attributes of *Celosia argentea* var. *cristata* L. as it helps in increasing meristems present in roots and shoots, stimulating stem elongation by increasing cell size and number, enhancing leaf growth and expansion which is responsible for making plant larger and longer as compared to non-treated plants. The results of the current study verify our hypothesis that application of gibberellic acid increased the plant height, leading to taller plants (Table 1).

There are significant effects of GA_3 on growth and physiological characteristics of *C. argentea* with the alleviating role of GA_3 foliar application. Foliar application of GA_3 increased growth attributes like leaf size, which is influenced by several factors, including water availability, which is often linked to changes in leaf size (Gholamzadeh et al., 2022). *Celosia cristata* L. often faces the challenge of bending and lodging stem which results in decreasing the appearance of plant. GA_3 treatment showed significant difference among the control resulting in stronger stem. (Abood et al., 2022). Results revealed that GA_3 may promote the development of sclerenchyma cells, which provide mechanical strength and support, resulting in thicker and stronger plant stem diameter. Moreover, it increases the stimulation of cytokinin hormone which leads to rapid division of cells leading to stem elongation and increased plant stem diameter. Respectively, leading to increase in fresh mass of flower, dry mass of flower and flower quality (Table 1).

GA_3 seems promising for maintaining chlorophyll content in celosia and acts as a receptor for the metabolites of food and transports them to the top of the apical meristem, leading to cell division and

chlorophyll content as compared to control. Moreover, findings of this study is in accordance with (Sardoei et al., 2014) who stated that the chlorophyll meter measures the relative density of leaf chlorophyll by analyzing the amount of light that traveled through the leaf and chlorophyll has the greatest absorption rate in two specific wavelengths: blue and red. Results of the investigation showed that the highest chlorophyll content of *Ficus benjamina*, *Schefflera arboricola* and *Dizigotheeca elegantissima* foliage plants was achieved when plants were subjected to foliar application of GA_3. Superoxide dismutase is a crucial antioxidant enzyme that aids plants in fighting against oxidative stress. Moreover, the application of GA_3 can stimulate the antioxidant defense system in plants, particularly ornamental species, by enhancing the activities of SOD and POD, glutathione S-transferase, and catalase (Pradeepkumar et al., 2020). This suggested that an intricate interaction between plant growth regulators such as GA_3 and antioxidant defense mechanisms in ornamental plants showing that this interaction can result in elevated levels of biochemical attributes activity in plants (Fig 1).

Modulating the number of stomata on the lower surface of leaves in decorative plants using GA_3, it can have substantial consequences for the productivity and excellence of crops (Maurya and Singh, 2022). The finding of our experiment showed GA_3 interacts with other plant hormones, such as auxin and ethylene, to regulate stomatal development. This increase in stomatal density and size can have important implications for plant growth and productivity like improved photosynthesis and enhanced water transport. Adaxial stomata are openings in the epidermis of a leaf's upper surface contributing to the leaf's photosynthesis. The administration of GA_3 has been found to impact stomatal density in plant leaves. These findings are in line with (Janowska et al., 2014) research on *Zantedeschia albomaculata* cv. 'Albomaculata' showed that the combination of benzyladenine and GA_3 at various doses led to changes in stomatal structure, with bigger stomata and reduced numbers detected in the upper and lower leaf epidermis. GA_3 treatment leads to increased leaf cell area, which can contribute to alterations in lamina thickness (Manoharlal et al., 2018) (Fig 2).

GA_3 plays a crucial role in plant physiology, particularly in regulating stomatal behavior leading to increase in abaxial stomatal area of *Passiflora edulis* (Cezar et al., 2015). Results of this study revealed that GA_3 has been connected to the modulation of stomatal guard cells, altering the abaxial stomatal area and leading to better physiological characteristics such as increased plant height, foliage density, and leaf cell area. The finding of our experiment has shown significant increase in abaxial stomatal area (Fig 3). The midrib aids the leaf in maintaining an upright position and provides strength against wind, while also supporting optimal exposure to sunlight. The cross-sectional analysis of a leaf from *Celosia argentea* revealed a highly prominent midrib that had an oblong to round shape under effect of GA_3 (Iiobdida et al., 2013). The finding of our experiment has shown significant increase in midrib thickness (Fig 3). The administration of GA_3 has been demonstrated to have numerous impacts on plants, including affecting the adaxial stomatal area (Manoharlal et al., 2018). Because GA_3 application can lead to increased plant height, foliage density, leaf cell area, and trichome density, suggesting a potential impact on stomatal properties (Fig 3).

The application of GA_3 has been proven to have a considerable impact on vascular bundles which serve as conduits within a plant, comprising xylem and phloem, facilitating the absorption of water and dissolved minerals. GA_3 spraying can lead to a considerable increase in vegetative development parameters, including the number of vascular bundles in Cress plant (*Lepidium sativum* L.) (Altememe and Hachim, 2020). The present study was conducted to know how foliar application of gibberellic acid alters the number of vascular bundles. The results have revealed that there is a significant number of increases in

vascular bundles (Fig 4). The gibberellic acid plays a crucial function in modifying phloem area in plants (Maske et al., 2020). The results of this study revealed that there is a significant increase in the phloem area due to application of GA_3 (Fig 4). The capacity of xylem in flowers alongside other organs to withstand embolism during foliar application of plant hormones like GA_3 is beneficial for gaining a more profound comprehension of the development of floral plants and water transportation in other plant organs (Blackman et al., 2010). The noticed increase in xylem area is due to the application of gibberellic acid (Fig 4).

Conclusion:

This study examined that the impact of growth regulator GA_3 on the physiological, biochemical, and morphological characteristics of *Celosia cristata* 0f the growth regulators evaluated GA_3 administered as a foliar spray had the most pronounced beneficial effects. Plants subjected to GA_3 foliar spray demonstrated optimal outcomes, including higher growth indices, elevated chlorophyll content, and improved water relations. The results indicate that GA3 foliar spraying is an effective approach to enhance the quality and productivity of *Celosia cristata*.

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