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Synergistic effect of gibberellic acid and salicylic acid on growth, flowering and yield of French Marigold (*Tagetes patula*) cv. Pusa Arpita

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ABSTRACT

The present study explores the combined effects of gibberellic acid (GA_3) and salicylic acid (SA) on the growth, flowering, and yield of French marigold (*Tagetes patula* cv. Pusa Arpita), conducted during the winter season of 2021-22 at the Horticulture Research Block, Janta Vedic College, Baraut, Baghpat, Uttar Pradesh. Utilizing a Randomized Block Design (RBD), the experiment included eight treatments, with a control group receiving distilled water, and each treatment was replicated three times. The treatments involved varying concentrations of GA_3 (100 ppm and 150 ppm) and SA (150 ppm and 300 ppm), applied both individually and in combination. Results showed significant improvements in growth parameters when GA_3 at 150 ppm was combined with SA at 300 ppm, resulting in a plant height of 67.12 cm, a plant spread of 58.14 cm, an average of 17.60 primary branches per plant, 24.45 secondary branches per plant and 310.44 leaves per plant, all significantly higher than the control group. Additionally, this treatment i.e T_8 (GA_3 150 ppm + SA 300 ppm) led to earlier flowering at 56.30 days to first bloom and an extended flowering duration of 50.20 days, along with improved yield metrics of 150.67 flowers per plant and a total yield of 19.40 tonnes per hectare. These findings indicate that the combined application of GA_3 and SA not only enhances vegetative growth but also significantly boosts floral yield, suggesting that these plant growth regulators can greatly improve productivity in French marigold cultivation and highlighting their potential benefits.

KEYWORDS

Synergistic Effect, Gibberellic Acid, Salicylic Acid, Growth, Flowering, Yield, Marigold

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French marigold (*Tagetes patula*) is a prominent flower in ornamental horticulture, known for its vibrant blooms and adaptability to various agroclimatic conditions (Singh, 2006). This species is widely cultivated not only for its aesthetic appeal but also for its significant role in the floral industry, including applications in landscaping, garland making and the extraction of lutein (a natural pigment with both medicinal and industrial uses). The increasing demand for marigolds in domestic and export markets has prompted research focused on enhancing growth and yield attributes. Plant growth regulators (PGRs) like gibberellic acid (GA_3) and salicylic acid (SA) are pivotal in optimizing plant physiology, promoting cell elongation, division and flowering. GA_3 is well-established as a growth promoter that influences cell elongation, division and flowering, which can lead to improvements in plant height, biomass and overall yield (Meena *et al*., 2017 and Kumar *et al*., 2017).

Conversely, SA is recognized for its role in stress mitigation, enhancement of photosynthesis and induction of flowering (Mahadi *et al*., 2020). Recent studies have indicated that the combined application of these PGRs may produce synergistic effects, resulting in superior growth performance and yield compared to their individual applications. Despite the promising potential of GA_3 and SA, there remains a limited body of research evaluating their integrated effects specifically on French marigold. Therefore, the present investigation aims to assess the synergistic impact of GA_3 and SA on the growth, flowering and yield attributes of French marigold (*Tagetes patula* cv. Pusa Arpita). This study seeks to contribute valuable insights into effective cultivation practices that can enhance productivity in response to the growing market demand.

Materials and Methods

The present investigation was conducted at the Horticulture Research Block of Janta Vedic College, Baraut, Baghpat, Uttar Pradesh, during the winter season of 2021-22. Baraut is situated at latitude of 29º 6` North and a longitude of 77º 16` East, at an altitude of 231 meters above mean sea level. The climate of the Baghpat region is characterized as subtropical, with very hot summers, relatively cool winters, and an uneven distribution of rainfall. The soil in the experimental field was sandy loam, which is well-suited for marigold cultivation. At the time of land preparation, well-decomposed farmyard manure (FYM) was applied at a rate of 30 tons per hectare.

The recommended dose of nitrogen, phosphorus, and potassium (NPK) was provided in the form of urea, single super phosphate and muriate of potash. Uniformly sized and healthy seedlings of French marigold cv. Pusa Arpita, aged 25 days, were transplanted at a spacing of 60 cm × 45 cm on raised beds during the first week of November. The experiment was laid out in a Randomized Block Design (RBD) with eight treatments along with a control and replicated trice. The treatments included varying concentrations of gibberellic acid (GA_3) and salicylic acid (SA), applied both individually and in combination. The detail of treatments are: T_0 - control (sprayed with distilled water), T_1 - GA_3 100 ppm, T_2 - GA_3 150 ppm, T_3 - SA 150 ppm, T_4 - SA 300 ppm, T_5 - GA_3 100 ppm + SA 150 ppm, T_6 - GA_3 100 ppm + SA 300 ppm, T_7 - GA_3 150 ppm + SA 150 ppm and T_8 - GA_3 150 ppm + SA 300 ppm. These growth regulators were applied as foliar sprays to the respective plots according to the treatment schedule in two doses: ten days after transplanting and twenty days after the first spray. Standard cultural practices were adhered to throughout the study, including timely irrigation, weeding and fertilization as per recommended guidelines. The growth parameters such as plant height, number of branches, Number of leaves per plant, flowering duration and yield attributes were recorded at regular intervals to assess the effects of the applied treatments on the growth and productivity of French marigold. Observations were recorded on five randomly selected plants from each treatment to assess growth and yield attributes. The collected data were analyzed statistically following the standard procedures outlined by (Gomez and Gomez, 1985).

Results and Discussion

Growth Attributes

The results of the exogenous application of gibberellic acid (GA_3) and salicylic acid (SA) on the growth attributes of French marigold cv. Pusa Arpita are presented in table 1. The data indicate that the application of these plant growth regulators significantly enhanced various growth parameters compared to the control group.

Plant Height and Spread

The highest plant height (67.12 cm) and plant spread (58.14 cm) were observed in the treatment with GA_3 at 150 ppm combined with SA at 300 ppm (T_8). This increase can be attributed to the role of GA_3 in promoting cell elongation and division, which is consistent with previous studies that reported similar enhancements in plant height due to GA_3 application (Kumar *et al*., 2010; Poudel and Subedi, 2020). The control plants exhibited a height of only 60.33 cm, highlighting the effectiveness of the growth regulators in improving vertical and lateral growth.

Number of Branches

The number of primary branches per plant was maximized in T_8 (17.60), while T_7 (GA_3 150 ppm + SA 150 ppm) also showed significant improvement (17.20).

Similarly, the number of secondary branches was highest in T_8 (24.45), indicating that the combined application of GA_3 and SA not only enhances overall growth but also promotes branching, which is crucial for flower production (Zhang *et al*., 2021).

Leaf Attributes

The number of leaves per plant reached its peak in T_8 with 310.44 leaves, compared to 280.75 leaves in the control group. This increase suggests that the application of these PGRs effectively stimulates foliar development, which is essential for photosynthesis and overall plant vigor (Basit *et al*., 2018). Leaf length and width also showed slight improvements across treatments, with T_8 achieving a leaf length of 19.96 cm and width of 12.43 cm. The results underscore the synergistic effect of combining GA_3 and SA on enhancing growth attributes in French marigold. The observed improvements align with findings from other studies that have demonstrated the positive impact of these growth regulators on plant morphology and productivity (Kumar *et al*., 2020).

Flowering and Yield Attributes

The effects of exogenous applications of gibberellic acid (GA_3) and salicylic acid (SA) on the yield attributes of French marigold cv. Pusa Arpita are summarized in Table 2. The data reveal that the application of these plant growth regulators significantly influenced various yield parameters, including days to first flowering, days to 50% flowering, duration of flowering, number of flowers per plant and flower yield (tonnes/ha).

Days to First Flowering and Days to 50% Flowering

The earliest days to first flowering (56.30 days) and days to 50% flowering (65.33 days) were recorded in T_8, which involved the combined application of GA_3 at 150 ppm and SA at 300 ppm. This treatment resulted in a significant reduction in the time taken for flowering compared to the control (62.55 days for first flowering and 72.10 days for 50% flowering). Such findings are consistent with previous research indicating that GA_3 promotes early flowering by enhancing hormonal activity and stimulating flower bud differentiation (Kumar *et al*., 2010; Kumar *et al*., 2020).

Duration of Flowering

The duration of flowering was significantly extended in T_8, lasting for 50.20 days, compared to only 40.33 days in the control group. This increase suggests that the synergistic effect of GA_3 and SA not only accelerates the onset of flowering but also prolongs the blooming period, which is essential for maximizing floral yield (Poudel and Subedi, 2020).

Number of Flowers per Plant

The highest number of flowers per plant was observed in T_8 with 150.67 flowers, significantly higher than the control's 102.45 flowers. This enhancement in flower production can be attributed to improved vegetative growth and optimal hormonal balance facilitated by the application of GA_3 and SA (Zhang *et al*., 2021). Treatments T_7 (140.20 flowers) and T_6 (136.72 flowers) also showed substantial increases, reinforcing the positive impact of these growth regulators on flower yield.

Flower Yield

The overall flower yield was maximized at 19.40 tonnes/ha in T_8, demonstrating a clear advantage over the control group, which yielded only 18.12 tonnes/ha. This increase in yield aligns with findings from other studies that have reported similar enhancements due to the application of GA_3 and SA in various ornamental crops (Basit *et al*., 2018).

Conclusion

The results indicate that the exogenous application of gibberellic acid and salicylic acid significantly enhances growth and yield attributes in French marigold cv. Pusa Arpita. The combined treatment not only promotes earlier flowering but also increases the duration of blooming and overall flower production, thereby improving yield potential. These findings provide valuable insights for optimizing cultivation practices aimed at meeting the growing demand for marigold flowers in both domestic and export markets.

Table 1. Effect of exogenous application of gibberellic acid and salicylic acid on growth attributes of French marigold cv. Pusa Arpita

Treatment	Plant Height (cm)	Plant Spread (cm)	Number of Primary Branches / Plant	Number of Secondary Branches / Plant	Number of Leaves / Plant	Leaf Length (cm)	Leaf Width (cm)
Control	60.33	53.80	14.15	20.25	280.75	19.80	12.34
T_1-GA_3 100 ppm	64.25	54.46	16.45	22.60	294.21	19.88	12.37
T_2-GA_3 150 ppm	65.30	56.20	16.75	23.35	295.22	19.90	12.38
T_3-Salicylic acid 150 ppm	62.44	54.12	14.90	20.75	284.24	19.82	12.36
T_4-Salicylic acid 300 ppm	63.12	54.22	15.35	21.05	286.76	19.83	12.35
T_5- GA_3 100 ppm + Salicylic acid 150 ppm	65.90	56.90	16.90	23.00	300.10	19.88	12.39
T_6-GA_3 100 ppm + Salicylic acid 300 ppm	66.14	57.10	17.00	23.15	306.20	19.91	12.40
T_7-GA_3 150 ppm + Salicylic acid 150 ppm	66.42	57.66	17.20	24.10	305.60	19.94	12.41
T_8-GA_3 150 ppm + Salicylic acid 300 ppm	67.12	58.14	17.60	24.45	310.44	19.96	12.43
CD (p=0.05)	1.90	1.55	1.22	1.73	5.47	0.24	0.17

Table 2. Effect of exogenous application of gibberellic acid and salicylic acid on yield attributes of French marigold cv. Pusa Arpita

Treatment	Days to First Flowering	Days to 50 % Flowering	Duration of Flowering (Days)	Number of Flowers per Plant	Yield (Tonnes / ha)
Control	62.55	72.10	40.33	102.45	18.12
T_1-GA_3 100 ppm	59.20	68.90	45.50	130.67	19.10
T_2-GA_3 150 ppm	58.67	68.45	46.67	134.20	19.24
T_3-Salicylic acid 150 ppm	60.45	70.00	41.90	120.67	18.40
T_4-Salicylic acid 300 ppm	60.15	69.15	42.20	124.30	18.67
T_5- GA_3 100 ppm + Salicylic acid 150 ppm	58.60	66.67	47.50	132.50	19.28
T_6-GA_3 100 ppm + Salicylic acid 300 ppm	57.67	66.80	48.00	136.72	19.30
T_7-GA_3 150 ppm + Salicylic acid 150 ppm	57.33	66.20	48.67	140.20	19.34
T_8-GA_3 150 ppm + Salicylic acid 300 ppm	56.30	65.33	50.20	150.67	19.40
CD (p=0.05)	1.73	1.90	1.55	6.70	0.24

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