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Study on the physiological impact of salicylic acid and kinetin on growth dynamics, floral morphogenesis and seed yield of Sweet William

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ABSTRACT

This study investigated the impact of salicylic acid and kinetin on the growth, flowering, and seed yield of Sweet William (*Dianthus barbatus* L.). The concentration of SA ranged from 10 to 40 ppm and for kinetin it was 5 to 20 ppm alongwith a control. It was revealed that SA at 20 ppm induced the maximum plant height at 60 days after treatment (DAT), while kinetin at 15 ppm exhibited the highest plant height at 90 DAT. SA at 20 ppm influenced primary and secondary branches, stem diameter, and leaf count. It accelerated bud initiation at 55 DAT and prompted the earliest floral anthesis at 66.16 DAT, acting as a blooming time regulator. Kinetin at 20 ppm stimulated the highest number of flowers per plant (543.83) and increased the fresh and dry weight of flowers at 10 ppm. Additionally, kinetin at 20 ppm enhanced the total seed production. SA at 40 ppm recorded the highest seed yield per plant and 1000-seed weight as well. Optimal treatment involves SA at 20 ppm for enhanced, while kinetin at 20 ppm positively influences flower and seed production.

Key words: *Dianthus barbatus*, Blooming time, Bud initiation, Seed weight, PGRs.

INTRODUCTION

Ornamental annuals complete their life cycle within a single growing season and hold substantial significance in floriculture for garden adornment and potted plant arrangements. Beyond various bed sizes, these herbaceous plants thrive in rock gardens, herbaceous borders, window baskets, lily pool sides, and shrubberies, enhancing diverse landscapes. India is endowed with varied agro-climatic zones, supports the production of delicate floriculture products. Post-liberalization, the Indian floriculture industry witnessed substantial export growth, transitioning from sustenance to commercial production. In the fiscal year 2021-22, India's floriculture production covered 283 thousand hectares, yielding 3128 thousand tonnes, achieving a productivity rate of 11.10% (Source: Ministry of Agriculture and Farmers Welfare). Floriculture exports from India reached Rs. 707.81 Crores/ USD 88.38 Million in 2022-23, with major importing nations being the USA, Netherlands, UAE, UK, and Germany. Over 300 export-oriented units contribute to this flourishing industry, with more than half of the country's floriculture products originating from Karnataka, Andhra Pradesh, Tamil Nadu, and Madhya Pradesh. Collaborations with foreign companies position the Indian floriculture industry to expand its global trade share (source: apeda.gov.in).

Dianthus barbatus L., commonly known as Sweet William belongs to the Caryophyllaceae family, serves as a winter annual extensively utilized in landscaping and cut flower production. Its edible petals, characterized by a moderate flavour, contribute versatility to various culinary delights, serving as decorative elements in salads, pastries, sweets, cold drinks, tea, and sorbet. Its adaptability extends further, enhancing the flavour profile of ice cream, sorbets, salads, dessert sauces, seafood, and stir-fries, making it a valuable asset in both horticulture and gastronomy. Growth regulators are pivotal in floriculture and play a significant role in managing the growth, flowering, and reproduction of annuals like Sweet William. Salicylic acid is a prominent plant phenolic compound, aids plants in responding to abiotic stimuli and pathogen attacks. When studied under normal conditions, salicylic acid influences various physiological processes crucial to plant growth, including inducing flowering, promoting root development, closing stomata, reducing transpiration, reversing abscisic acid effects, regulating gravitropism, and impacting photosynthesis and overall growth (Al-Abbasi *et al.*, 2). Its intrinsic role as a flowering regulator has been observed across diverse plant species, acting as a link between defence responses and reproductive development, influencing the timing of blooming.

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Kinetin, a cytokinin, is a natural plant growth hormone that significantly influences cell division. Regulating cell division and overall growth, kinetin provides stress tolerance to plants, supports flowering, promotes photosynthesis-related enzymes, and counteracts apical dominance by increasing lateral bud formation. External application of kinetin delays senescence by boosting RNA and protein synthesis, demonstrating success in inducing flowering in short-day plants and supporting shoot bud development with high kinetin and low auxin levels (Abou-El-Ghait *et al*., 1). In light of the aforementioned considerations, this experiment was undertaken to examine the influence of salicylic acid and kinetin on the growth, flowering, and seed yield of Sweet William.

MATERIALS AND METHODS

The experiment was conducted at the Research Farm of the Dept. of Horticulture, Institute of Agricultural Sciences, BHU, Varanasi (U.P.), India during 2021-2022 on the winter annual, Sweet William (*Dianthus barbatus*). The seeds were obtained from the Horticulturist Unit, Banaras Hindu University, Varanasi. Nursery raising commenced in November 2021, with a 3.6 × 1 m² bed. Seeds were sown in lines, covered with a thin layer of Farm Yard Manure (FYM), and lightly irrigated for a 10-day germination period. Regular irrigation to maintain moisture and manual weeding ensured a weed-free nursery bed. Polyethylene sheet cover protected the seedlings from birds and chilling winds. After 25 days, healthy 3-4 leaf seedlings were ready for transplanting. Field preparation was completed on November 29, 2021. Transplanting was done at the spacing of 60 cm between rows and 50 cm between seedlings. Evening transplanting was done as it avoided sunlight exposure at the time. Irrigation involved initial daily watering using a watering can and subsequent weekly flooding was done.

The experiment was carried out in a Randomized Block Design (RBD) with three replications. The data recorded for growth, flowering, and seed yield during the investigation were statistically analysed for analysis of variance (ANOVA) as suggested by Panse and Sukhatme (12). The study aimed to evaluate the impact of different levels of plant growth regulators, specifically salicylic acid (10, 20, 30 and 40 ppm) and kinetin (5, 10, 15 and 20 ppm), along with a control group receiving water spray. The treatments were applied once after transplanting, and the experiment was conducted under open conditions.

RESULTS AND DISCUSSION

Significant variations in plant growth parameters were observed with different treatments. Salicylic acid at 20 ppm (T_2) resulted in the maximum plant height (44.61 cm) at 60 days after treatment (DAT), while kinetin at 15 ppm (T_7) exhibited the highest plant height (61.25 cm) at 90 DAT (Table 1). This aligns with previous studies reporting the influence of salicylic acid on metabolic processes and kinetin on mitotic cell division, affecting plant height (Youssef *et al.*, 16; Gad *et al.,* 5; Zeb *et al.*, 17; Basit *et al*., 3). Salicylic acid at 40 ppm (T_4) led to the maximum branches (92.84) at 90 DAT (Table 1). This outcome is attributed to salicylic acid's role as a signal molecule, enhancing nutrient integration and immune response, thereby influencing primary branch development (Kumar *et al.*, 9 and Abou-El-Ghait *et al*., 1). Kinetin at 20 ppm (T_8) exhibited the maximum spread (60.50 cm) at 90 DAT (Table 2). The increased number of branches in kinetin-treated plants contributed to enhanced lateral expansion (Sonvir *et al.*, 14; Kumar *et al*., 10). Similarly, the use of kinetin at 20 ppm (T_8) led to the highest number of leaves per plant (493.00) (Table 2), consistent with kinetin's known role in facilitating cell division and expansion, resulting in increased leaf proliferation (Al-Abbasi *et al.,* 2; El Bably *et al.*, 4; Basit *et al.*, 3). Furthermore, kinetin at 15 ppm (T_7) exhibited the highest fresh (1.62 g) and dry weight of leaves (0.34 g) (Table 2). These findings are in agreement with kinetin's influence on cell division, enlargement, and chlorophyll synthesis by Youssef *et al.* (16) and El Bably *et al.* (4). Additionally, kinetin at 15 ppm (T_7) resulted in the largest leaf area (92.26 cm^2) (Table 2), emphasizing its role in promoting cell proliferation and enlargement (Ramy *et al.*, 13).

With regard to flowering parameters, salicylic acid at 20 ppm (T_2) accelerated bud initiation at 55 DAT and also earliest floral anthesis at 66.16 DAT (Table 3). Salicylic acid, acting as a blooming time manager, facilitated early flowering and bud sprouting by influencing photoperiod-dependent and independent pathways. This aligns with findings by Youssef *et al.* (16) in Barbados lily, Ghatas *et al.* (6) in day lily, Zeb *et al.* (17) in zinnia, and Vijayakumar *et al.* (15) in China aster. Data in Table 3 reveals a substantial difference in flower withering time among treatments, with T_4 (40 ppm salicylic acid) showing prolonged withering at 92.83 DAT. Salicylic acid contributed to extending the shelf life of flowers by minimizing electrolytic leakage during withering. Similar results were observed by Zeb *et al.* (17) in Zinnia and Ramy *et al.* (13) in *Gaillardia pulchella*.

Treatment T_2 (salicylic acid 20 ppm) displayed a maximum bud diameter of 4.85 mm and also produced the largest flower diameter (32.10 mm), attributed to increased flavonoid content positively affecting the flower size and overall plant growth.

Table 1. Effect of salicylic acid and kinetin on the growth parameters at 60 and 90 days after treatment (DAT) in Sweet William.

Sl. No.	Treatment	Plant height (cm)		No. of primary branches per plant		No. of secondary branches per plant	
		(60 DAT)	(90 DAT)	(60 DAT)	(90 DAT)	(60 DAT)	(90 DAT)
T_1	Salicylic acid (10 ppm)	32.28	56.85	13.00	89.33	8.33	25.50
T_2	Salicylic acid (20 ppm)	44.61	57.86	13.83	88.50	13.33	35.66
T_3	Salicylic acid (30 ppm)	28.45	53.21	10.83	86.00	11.83	32.83
T_4	Salicylic acid (40 ppm)	37.63	55.85	8.66	92.84	8.66	26.50
T_5	Kinetin (5 ppm)	27.27	56.73	13.00	88.50	16.83	35.66
T_6	Kinetin (10 ppm)	32.65	52.55	10.50	85.16	23.83	44.16
T_7	Kinetin (15 ppm)	34.31	61.25	9.33	92.83	12.16	29.33
T_8	Kinetin (20 ppm)	38.40	60.26	13.67	92.50	22.66	45.00
T_9	Control	25.28	51.63	8.00	77.50	7.66	23.66
S.Em±		0.84	1.40	0.86	1.11	0.48	1.35
C.D. (5%)		2.56	4.23	2.60	3.36	1.47	4.10

Table 2. Effect of salicylic acid and kinetin on the plant spread, stem diameter and leaves parameters in Sweet William.

Sl. No.	Treatment	Plant spread (cm) 60 DAT	Plant spread (cm) 90 DAT	No. of leaves per plant	Fresh weight of leaves (g)	Dry weight of leaves (g)	Leaf area (cm^2)
T_1	Salicylic acid (10 ppm)	34.17	53.68	362.66	0.84	0.25	68.74
T_2	Salicylic acid (20 ppm)	34.31	57.33	450.00	1.29	0.27	43.53
T_3	Salicylic acid (30 ppm)	33.69	56.17	282.83	1.33	0.28	37.63
T_4	Salicylic acid (40 ppm)	31.67	53.63	443.66	1.30	0.31	55.00
T_5	Kinetin (5 ppm)	31.69	49.71	295.50	0.51	0.13	44.00
T_6	Kinetin (10 ppm)	33.78	57.25	333.50	0.83	0.22	58.73
T_7	Kinetin (15 ppm)	31.56	47.33	249.00	1.62	0.34	92.26
T_8	Kinetin (20 ppm)	34.18	60.50	493.00	1.56	0.33	76.80
T_9	Control	31.20	44.50	167.16	0.82	0.21	41.03
S.Em±		0.96	0.84	8.87	0.18	0.03	1.46
C.D. (5%)		NS	2.55	26.84	0.54	0.08	4.43

Consistent findings were reported by Zeb *et al.* (17) on zinnia, and Ramy *et al.* (13) on *Gaillardia*. Salicylic acid's influence on biochemical and physiological processes contributed to enhanced vegetative growth and efficient translocation of photosynthetic products. Grown *et al.* (7) observed similar results in sunflower. A significant impact of salicylic acid and kinetin was observed in the number of flowers per plant (Table 3). T_8 (kinetin 20 ppm) yielded the highest number of flowers per plant at 543.83, attributed to kinetin's role in elevating endogenous cytokinin levels, acting as a floral stimulus. Comparable results were reported by Pal *et al.* (11) on rose and Ramy *et al.* (13) on *Gaillardia*. Significant variations in fresh and dry weight of flowers were also observed, with T_6 (kinetin 10 ppm) showing significantly higher values (7.06 and 1.98 g, respectively) (Table 3). This can be attributed to kinetin's foliar application, ensuring rapid nutrient transfer and effective absorption, as supported by Youssef *et al.* (16), Ghatas *et al.* (6), El Bably *et al.* (4), Abou-El-Ghait *et al.* (1) and Ramy *et al.* (13).

When compared to the control, kinetin at 20 ppm (T_8) produced the highest number of capsules per plant (512.17) (Table 4; Fig. 1), indicating the role of kinetin in promoting proteins and sugar biosynthesis, thereby enhancing flower growth and capsule formation (Hussain *et al.,* 8; Abou-El-Ghait *et al.*, 1). Compared to the control, kinetin at 20 ppm (T_8) produced the highest number of seeds per capsule (48.33) (Table 4; Fig 1), indicating

Table 3. Effect of salicylic acid and kinetin on the bud initiation and flowering parameters in Sweet William.

Sl. No.	Treatment	Days to bud initiation	Days to flower anthesis	Days to withering of flower	Bud diameter (mm)	Flower diameter (mm)	No. of flowers per plant	Fresh weight of flowers (g)	Dry weight of flowers (g)
T_1	Salicylic acid (10 ppm)	62.00	75.33	89.33	4.11	24.20	439.66	4.49	0.94
T_2	Salicylic acid (20 ppm)	55.00	66.16	77.50	4.85	32.10	532.16	5.67	1.59
T_3	Salicylic acid (30 ppm)	70.00	78.66	88.50	4.36	20.55	360.16	4.60	0.97
T_4	Salicylic acid (40 ppm)	72.66	83.66	92.83	4.42	20.89	540.00	3.84	0.94
T_5	Kinetin (5 ppm)	57.16	76.50	86.00	4.37	24.99	505.83	5.94	1.34
T_6	Kinetin (10 ppm)	72.33	78.66	92.50	4.80	24.97	434.00	7.06	1.98
T_7	Kinetin (15 ppm)	73.33	82.50	92.83	4.63	26.47	376.50	5.01	1.37
T_8	Kinetin (20 ppm)	66.66	74.66	85.16	4.76	23.96	543.83	6.57	1.81
T_9	Control	67.16	79.33	88.50	4.20	20.97	340.33	5.08	0.80
	S.Em±	1.05	1.17	1.11	0.09	1.03	14.95	0.51	0.18
	C.D. (5%)	3.20	3.55	3.36	0.29	3.13	45.23	1.55	0.56

its positive impact on seed development (Grown *et al.*, 7). Salicylic acid at 20 ppm (T_2) displayed the earliest capsule formation (87.00 DAT) and capsule maturation (113.66 DAT) (Table 4; Fig. 1), suggesting improved CO_2 assimilation and nutrient uptake (Zeb *et al.*, 17). Data presented in Table 4 and illustrated in Fig. 1 showed significant differences in seed yield per plant due to various treatments. The highest seed yield per plant (11.46 g) was found in treatment T_4 *i.e.*, salicylic acid 40 ppm, which was at par with treatment T_2 *i.e.*, salicylic acid 20 ppm (9.42 g). Maximum test weight (2.35 g) was observed in treatment T_4 *i.e.*, salicylic acid 40 ppm, which was at par T_2 (2.10 g) thus highlighting its positive influence on seed production (Grown *et al.*, 7; Kumar *et al.,* 9).

In conclusion, the results from this experiment provide valuable insights into the specific effects of salicylic acid and kinetin on the vegetative growth, flowering, and seed yield of Sweet William. Salicylic acid at 20 ppm (T_2) accelerated bud initiation at 55 DAT and resulted in the earliest floral anthesis at 66.16 DAT. It functions as a regulator of blooming time, consistent with previous findings. Kinetin at 20 ppm (T_8) increased the number of flowers per plant, while T_6 (kinetin 10 ppm) showed higher fresh and dry weight of flowers. These results align with the roles of salicylic acid and kinetin in influencing flowering parameters and enhancing overall plant growth. Further research could explore the underlying mechanisms driving these responses and expand

Table 4. Effect of salicylic acid and kinetin on capsule formation and seed yield parameters in Sweet William.

Sl. No.	Treatment	No. of capsules per plant	No. of seeds per capsule	Days to complete capsule formation	Days to capsule maturation	Seed yield per plant (g)	1000-seed weight (g)
T_1	Salicylic acid (10 ppm)	421.38	47.72	93.00	120.66	7.35	1.15
T_2	Salicylic acid (20 ppm)	436.88	44.16	87.00	113.66	9.42	2.10
T_3	Salicylic acid (30 ppm)	339.06	44.33	91.50	117.83	8.70	1.02
T_4	Salicylic acid (40 ppm)	501.50	48.16	96.66	124.16	11.46	2.35
T_5	Kinetin (5 ppm)	443.66	44.00	87.33	114.33	6.00	1.51
T_6	Kinetin (10 ppm)	374.46	48.00	93.33	120.66	6.21	1.97
T_7	Kinetin (15 ppm)	333.96	46.00	95.50	124.00	4.81	1.49
T_8	Kinetin (20 ppm)	512.16	48.33	90.16	118.50	8.85	1.98
T_9	Control	320.00	45.50	92.16	119.83	4.75	1.19
	SEm±	2.30	0.95	0.84	1.04	0.67	0.10
	C.D. (5%)	6.97	2.88	2.54	3.17	2.04	0.30

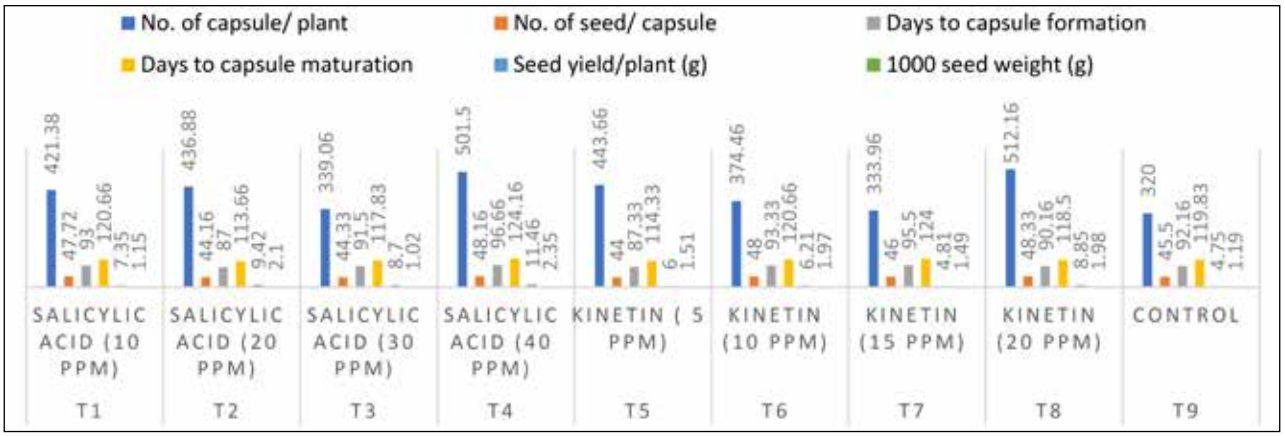

Fig. 1. Effect of salicylic acid and kinetin on capsule formation and seed yield parameters in Sweet William.

the scope to other plant species, fostering a deeper understanding of the intricate interplay between plant growth regulators and various physiological processes.

AUTHORS' CONTRIBUTION

Conceptualization of the original idea (TT and AKS); experiment designing (TT and PK); field/ lab experiments operation and data collection (PK, TS and YK); statistical analysis and interpretation (TT, PK, AKS); manuscript preparation (TT, AT, AD, MMS, SB and DS).

DECLARATION

The authors don't have any conflict of interests/ competing interests.

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