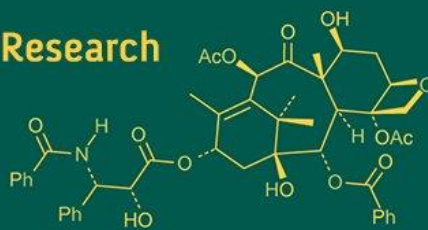


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Assessment of growth elicitors impact on morphological, flowering and corm attributes of gladiolus

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Abstract

Gladiolus is an economically important cut flower crop, and optimizing growth and flowering through growth elicitors is essential for enhancing yield and quality. The present study evaluated the effect of foliar applications of 6-benzyladenine (BA), naphthaleneacetic acid (NAA), and silicon (Si) on growth, flowering, and corm attributes of gladiolus cultivars 'Pusa Shanti' and 'Pusa Rajat'. The experiment was conducted in a two-factor split-plot design with ten treatments, comprising BA at 75, 150, and 225 ppm; NAA at 150, 300, and 450 ppm; Si at 1%, 2%, and 3%; and control, applied at 30, 50, and 70 days after planting. BA at 150 ppm significantly advanced 50% flowering and improved spike length, floret diameter, number of florets open at a time, spike and corm yield. NAA at 300 ppm enhanced cormel production, while NAA at 450 ppm recorded maximum floret longevity, corm diameter, and single corm weight. Silicon at 3% increased leaf area and fresh plant weight, whereas 2% Si extended flowering duration and vase life. Significant cultivar × treatment interaction effects were observed for most traits, except number of shoots, leaves per plant, and rachis length. 'Pusa Rajat' produced superior spike and corm yields under 3% Si treatment. These findings suggest that foliar application of BA 150 ppm and Si 3% can be recommended for producing export-quality gladiolus spikes with improved yield and postharvest performance.

Keywords: Gladiolus, growth promoter, BA, NAA, foliar spray

1. Introduction

Gladiolus hybrida L., a monocotyledonous flowering plant, is an economically significant species within the Iridaceae family, comprising about 92 genus and more than 260-300 species. Its natural range encompasses Central and South Africa, as well as parts of Asia and Southern Europe. Due to its massive flower spikes with florets of brilliant colours, appealing shapes, varying sizes, and exceptional shelf life, gladiolus is referred to as the queen of bulbous flowers. Since it has short growing season (110-120 days), the gladiolus has the potential to meet both domestic needs and generate foreign exchange. In order to satisfy local demand, commercial growers are planting gladiolus in various parts of the country. However, the production and flower quality of gladiolus, particularly in terms of spike length, number and size of florets, and vase life, remain below international standards. Therefore, in order to meet export requirements and strengthen the local market, research is needed to enhance both the yield and quality attributes of gladiolus flowers. As a result, plant growth elicitors are widely known to increase plant yield by modifying growth, development, and stress responses. Efforts are being made to increase the performance of quality bulbous plants using growth elicitors in order to create an ideal bulb size of bulbous plants to meet the demand for a variety of bulbous ornamental crops.

In the floriculture industry, the use of plant growth elicitors has brought about a kind of revolution. The control of growth and flowering in many floral crops to produce high-quality produce is one of the many positive effects of various plant growth elicitors on various horticultural crops that have been documented. Use of growth regulators in gladiolus has received due attention only in the recent past and still information available is very scanty. To date, little research has been done on the effects of silicon, BA and NAA on gladiolus quality and productivity in order to enhance the crop's flowering and corm characteristics under Delhi conditions.

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Cytokinins, auxins and silicon (Si) play important roles in regulating plant growth, development, and postharvest quality. Cytokinins are involved in cell division, chloroplast differentiation, and the delay of leaf senescence (Asil *et al.*, 2011) [2], with 6-benzylaminopurine (BAP) shown to enhance leaf expansion, increase flower size (Nishijima *et al.*, 2006) [16], and prolong vase life in cut flowers by protecting proteins and chlorophyll from degradation (Faraji *et al.*, 2011; Emami *et al.*, 2011) [9, 7]. Auxins regulate a wide range of metabolic and developmental processes, with naphthaleneacetic acid (NAA) promoting blooming, reducing flower drop, improving fruit set, and delaying senescence; in gladiolus, NAA has been reported to significantly increase corm yield in both number and weight (Ravidas *et al.*, 1992; Kumar *et al.*, 2008) [18, 13]. Silicon, though not classified as an essential nutrient, is recognized as a functional element that enhances crop yield and quality by stimulating photosynthesis, reducing transpiration, and improving resistance to biotic and abiotic stresses, while also contributing to postharvest quality maintenance (Raven, 2003; Hodson & Sangster, 1999; Liang *et al.*, 2001; Seebold *et al.*, 2001; Zhou *et al.*, 2002) [17, 11, 14, 20, 23]. Therefore, this study aimed to examine the effects of elicitors on the growth, corm characteristics, and flower quality of the gladiolus varieties Pusa Rajat and Pusa Shanti under normal growing conditions.

2. Materials and Methods

The present investigation was conducted at the Division of Floriculture and Landscaping, Research Farm, ICAR-Indian Agricultural Research Institute (IARI), New Delhi, located at 28.4°N latitude, 77.1°E longitude, and an altitude of 250 m above mean sea level, during the period from October 2023 to April 2024. The experiment was laid out in a two-factor split-plot design with three replications, comprising ten treatments: control (T₁), BAP at 75 ppm (T₂), BAP at 150 ppm (T₃), and BAP at 225 ppm (T₄); NAA at 150 ppm (T₅), NAA at 300 ppm (T₆), and NAA at 450 ppm (T₇); and silicon (Si) at 1% (T₈), silicon (Si) at 2% (T₉), and silicon (Si) at 3% (T₁₀). All treatments were applied as foliar sprays at 30, 50, and 70 days after planting. Two gladiolus varieties, 'Pusa Shanti' and 'Pusa Rajat,' were used for the study.

Data were recorded on vegetative, flowering, and corm parameters. Vegetative traits included plant height (cm), number of shoots per corm, number of leaves per plant, leaf area (cm²), and fresh and dry weight of the plant (g) at flowering. Flowering attributes comprised days to spike emergence, days to first floret opening, days to 50% flowering, flowering duration (days), spike length (cm), spike weight (g), number of florets per spike, number of florets open at a time, rachis length (cm), floret length and diameter (cm), floret longevity (days), vase life of spike (days), number of spikes per plant, number of spikes per plot, and number of spikes per hectare. Corm and cormel parameters *viz.* corm diameter (cm), corm weight (g), number of corms and cormels per plant, number of corms and cormels per plot, weight of corms and cormels per plant (g), weight of cormels per plot (kg), number of corms per hectare, and cormel yield (q ha⁻¹) were recorded. The obtained data was analysed using OPSTAT software.

3. Results and Discussion

The present investigation revealed that growth elicitors exerted a marked influence on growth, flowering, spike quality, corm and cormel production in gladiolus.

Vegetative traits such as leaf area and fresh weight were significantly improved with elicitor applications (Table 1). Between the varieties, Pusa Shanti recorded a higher leaf area (436.04 cm²) and fresh weight (121.06 g) compared to Pusa Rajat (344.85 cm² and 90.64 g, respectively). Among the treatments, silicon at 3% proved most effective, recording the highest mean leaf area (556.57 cm²) and fresh weight (147.54 g), with maximum varietal responses of 599.93 cm² leaf area and 171.56 g fresh weight in Pusa Shanti. These findings suggest that silicon enhances vegetative growth by improving photosynthetic activity and structural integrity (Bayat *et al.*, 2013) [4]. The number of shoots per plant at 70 days after planting was, however, not significantly affected, indicating greater genetic control over this trait.

Flowering parameters were also significantly influenced (Table 1). Pusa Shanti attained 50% flowering earlier (123.01 days) compared to Pusa Rajat (126.30 days), with the minimum number of days required under BA @ 150 ppm (120.0 days). Notably, Pusa Rajat responded more favourably (117.67 days) than Pusa Shanti (122.33 days). The duration of flowering was longer in Pusa Rajat (15.80 days) than in Pusa Shanti (14.12 days), with the highest values recorded under silicon at 2% (21.43 and 15.90 days, respectively). The promotive role of BA in accelerating floral initiation and the contribution of silicon in delaying senescence have been earlier reported in gladiolus and other ornamentals (Chopde *et al.*, 2015 and Manasa *et al.*, 2017) [6, 15].

Significant improvement in spike and floral quality attributes was observed with elicitor application (Table 2). Pusa Shanti produced longer spikes (86.8 cm) and rachis length (53.16cm) than Pusa Rajat (78.1 cm and 52.13 cm). The maximum spike length (94.9 cm) was obtained with BA at 150 ppm, with varietal maxima of 104.10 cm in Pusa Shanti and 85.7 cm in Pusa Rajat. The number of florets open at a time was also highest under BA at 150 ppm (5.33), with varietal differences of 5.67 in Pusa Shanti and 5.00 in Pusa Rajat. Floret diameter was greater in Pusa Rajat (7.98 cm) than in Pusa Shanti (7.32 cm), but both varieties recorded the highest values under BA at 150 ppm (9.00 and 8.33 cm, respectively). Floret longevity was longer in Pusa Shanti (5.02 days) compared to Pusa Rajat (4.69 days), with the maximum mean value recorded under NAA at 450 ppm (6.23 and 5.10 days, respectively). Vase life was greater in Pusa Rajat (11.47 days) than in Pusa Shanti (10.45 days), with the longest mean life (12.08 days) recorded under silicon at 2%. The varietal × treatment interaction further showed that BA at 150 ppm gave the longest vase life in Pusa Rajat (13.37 days), while NAA at 300 ppm was superior in Pusa Shanti (12.13 days). Similar results have been documented earlier, where BA improved spike quality, while NAA and silicon extended vase life by maintaining membrane stability and delaying floret senescence (Tawar *et al.*, 2007; Baskaran *et al.*, 2009; Aier *et al.*, 2015) [22, 3, 1].

Corm and cormel production were also significantly influenced by elicitor applications (Table 3). Pusa Shanti recorded the maximum corm diameter (5.61 cm) and single corm weight (75.47 g) than Pusa Rajat (4.84 cm and 65.26 g, respectively). The application of NAA at 450 ppm resulted in the maximum corm diameter (6.07 cm) and weight (88.07 g), with varietal maxima of 94.91 g in Pusa Shanti and 84.0 g in Pusa Rajat. The number of corms per plant was higher in Pusa Rajat (1.70) than in Pusa Shanti (1.57), with BA at 150 ppm recording the maximum mean

(1.93), including the highest varietal value of 2.24 in Pusa Rajat. Cormel weight per plant was maximum in Pusa Shanti (4.48 g) compared to Pusa Rajat (3.67 g), with NAA at 300 ppm recording the highest mean (5.32 g), and varietal maxima of 5.76 g in Pusa Shanti and 4.88 g in Pusa Rajat. These findings confirm the stimulatory role of auxins in assimilate partitioning to underground storage organs (Song *et al.*, 2022) [21].

Elicitor treatments also had a strong impact on productivity traits (Table 4). The maximum number of spikes per hectare was recorded under BA at 150 ppm (2,55,297.2), with Pusa Rajat producing the highest (2,94,902.8 spikes ha⁻¹) compared to Pusa Shanti (2,51,666.7 spikes ha⁻¹). Similarly, corm production was higher in Pusa Rajat (2,57,991.4 ha⁻¹)

than in Pusa Shanti (2,40,626. ha⁻¹), with the maximum mean (2,98,034.0 ha⁻¹) obtained under BA at 150 ppm. The highest individual value was recorded in Pusa Rajat (3,50,413.9 corms ha⁻¹), while Pusa Shanti performed best under NAA at 150 ppm (2,83,920.0 ha⁻¹). Cormel yield was superior in Pusa Shanti (684.97 kg ha⁻¹) compared to Pusa Rajat (558.16 kg ha⁻¹), with NAA at 300 ppm producing the maximum mean (807.54 kg ha⁻¹), and varietal maxima of 876.92 kg ha⁻¹ in Pusa Shanti and 753.98 kg ha⁻¹ in Pusa Rajat. These results corroborate earlier reports that BA enhances spike and corm productivity by promoting cell division, whereas NAA enhances cormel yield by favouring assimilate translocation and storage (Aier *et al.*, 2015 and Manasa *et al.*, 2017) [1, 15].

Table 1: Effect of growth elicitors on vegetative parameters of gladiolus

Treatments	Leaf area (cm ²)			Fresh weight of plant (g)			Number of shoots per plant (70 DAP)			Days taken for 50% flowering			Flowering duration (days)		
	PS	PR	Mean	PS	PR	Mean	PS	PR	Mean	PS	PR	Mean	PS	PR	Mean
T ₁	448.0	374.4	411.2	86.95	103.32	95.14	1.53	1.71	1.62	127.43	126.67	127.05	10.10	13.80	11.95
T ₂	333.9	385.9	359.9	110.27	99.09	104.68	1.75	1.64	1.69	122.33	128.33	125.33	11.00	13.47	12.23
T ₃	492.8	365.4	429.1	126.03	93.53	109.78	1.53	1.97	1.75	122.33	117.67	120.00	12.10	17.63	14.87
T ₄	392.8	286.6	339.7	155.80	80.18	117.99	1.64	1.84	1.74	121.33	127.33	124.33	13.33	14.57	13.95
T ₅	337.0	315.2	326.1	134.82	80.87	107.85	1.41	1.76	1.59	120.67	129.33	125.00	14.53	16.33	15.43
T ₆	351.3	249.0	300.1	110.02	81.19	95.61	1.64	1.64	1.64	126.00	130.33	128.17	14.67	15.90	15.28
T ₇	428.6	309.6	369.1	104.98	87.52	96.25	1.42	1.75	1.59	126.33	122.33	124.33	14.77	15.30	15.03
T ₈	497.6	274.0	385.8	118.74	82.68	100.71	1.30	1.75	1.53	119.33	124.00	121.67	19.33	14.23	16.78
T ₉	478.6	375.2	426.9	91.40	74.43	82.92	1.86	1.75	1.81	123.00	131.33	127.17	15.90	21.43	18.67
T ₁₀	599.9	513.2	556.6	171.56	123.51	147.54	1.41	1.90	1.66	121.33	125.67	123.50	15.43	15.30	15.37
Mean	436.0	344.9		121.06	90.64		1.55	1.77		123.01	126.30		14.12	15.80	
	C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)	
Var(A)	14.01	2.1		2.86	0.44		NS	0.11		3.43	0.52		1.55	0.24	
Trt(B)	13.95	4.9		2.80	0.97		NS	0.13		3.31	1.15		1.75	0.61	
A*B	22.20	6.78		4.47	1.38		NS	0.35		5.30	1.66		2.72	0.75	
B*A	22.18	6.85		4.47	1.38		NS	0.20		5.31	1.63		2.69	0.85	

Table 2: Effect of growth elicitors on flowering parameters of gladiolus

Treatments	Spike length(cm)			Number of florets remain open at a time			Length of rachis (cm)			Floret diameter (cm)			Floret longevity (days)			Vase life (days)		
	PS	PR	Mean	PS	PR	Mean	PS	PR	Mean	PS	PR	Mean	PS	PR	Mean	PS	PR	Mean
T ₁	72.37	52.17	62.27	4.33	3.33	3.83	54.53	50.17	52.35	5.17	6.77	5.97	3.34	3.55	3.44	9.00	8.90	8.95
T ₂	97.00	77.20	87.10	4.67	4.00	4.33	55.83	53.27	54.55	7.33	7.80	7.57	4.23	4.66	4.44	10.43	12.77	11.60
T ₃	104.10	85.67	94.88	5.67	5.00	5.33	64.23	63.07	63.65	8.33	9.00	8.67	5.34	5.32	5.33	9.17	13.37	11.27
T ₄	94.50	82.37	88.43	5.00	3.67	4.33	59.27	51.50	55.38	6.80	8.57	7.68	5.90	4.55	5.22	10.40	11.13	10.77
T ₅	87.67	83.30	85.48	4.33	3.67	4.00	63.33	54.73	59.03	7.67	8.70	8.18	5.12	4.99	5.06	11.13	11.27	11.20
T ₆	85.60	81.33	83.47	4.33	4.33	4.33	53.50	43.67	48.58	7.97	7.40	7.68	5.23	5.10	5.17	12.13	10.30	11.22
T ₇	73.23	79.00	76.12	5.33	3.67	4.50	49.07	45.10	47.08	7.30	6.87	7.08	6.23	5.10	5.67	9.47	10.43	9.95
T ₈	82.50	88.47	85.48	5.33	4.33	4.83	53.00	50.63	51.82	8.17	8.20	8.18	4.56	4.55	4.56	12.03	11.47	11.75
T ₉	87.13	76.03	81.58	4.33	3.67	4.00	54.83	55.00	54.92	7.30	8.50	7.90	5.34	4.21	4.78	11.47	12.70	12.08
T ₁₀	84.30	75.40	79.85	4.33	3.33	3.83	53.73	54.13	53.93	7.17	7.97	7.57	4.90	4.88	4.89	9.30	12.33	10.82
Mean	86.84	78.09		4.77	3.90		56.13	52.13		7.32	7.98		5.02	4.69		10.45	11.47	
	C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)	
Var(A)	4.71	0.72		0.11	0.02		1.733	0.265		0.052	0.008		0.15	0.02		0.27	0.04	
Trt(B)	9.36	3.25		0.41	0.14		4.999	1.736		0.667	0.232		4.999	1.736		0.667	0.232	
A*B	13.69	2.27		0.58	0.06		NS	0.837		0.944	0.025		0.65	0.07		0.52	0.13	
B*A	13.16	4.42		0.56	0.19		NS	2.344		0.896	0.311		0.62	0.21		0.51	0.16	

Table 3: Effect of growth elicitors on corm parameters of gladiolus

Treatments	Diameter of corms (cm)			Weight of single corm (g)			Number of corms plant ⁻¹			Weight of cormels plant ⁻¹ (g)		
	PS	PR	Mean	PS	PR	Mean	PS	PR	Mean	PS	PR	Mean
T ₁	5.13	3.97	4.55	59.76	53.40	56.58	1.25	1.31	1.28	2.88	2.88	2.88
T ₂	5.37	4.53	4.95	63.33	64.39	63.86	1.67	1.56	1.61	3.58	2.38	2.98
T ₃	6.00	4.93	5.47	92.00	84.00	88.00	1.61	2.24	1.93	5.24	2.92	4.08
T ₄	5.03	5.13	5.08	62.87	63.56	63.21	1.56	1.76	1.66	4.13	4.03	4.08
T ₅	5.57	4.63	5.10	77.00	64.12	70.56	1.88	1.62	1.75	4.88	4.83	4.85
T ₆	5.93	4.53	5.23	82.56	76.89	79.72	1.54	1.40	1.47	5.76	4.88	5.32
T ₇	6.33	5.80	6.07	94.91	81.22	88.07	1.39	1.59	1.49	5.28	3.38	4.33
T ₈	5.90	5.57	5.73	76.52	51.67	64.10	1.65	1.67	1.66	4.58	3.83	4.20
T ₉	5.30	5.07	5.18	71.23	54.56	62.90	1.72	1.78	1.75	4.38	4.13	4.25
T ₁₀	5.53	4.27	4.90	74.46	58.78	66.62	1.43	2.04	1.74	4.13	3.48	3.80
Mean	5.61	4.84		75.47	65.26		1.57	1.70		4.48	3.67	
	C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)	
Var(A)	0.18	0.03		2.11	0.32		0.03	0.00		0.23	0.04	
Trt(B)	0.43	0.15		6.66	2.31		0.15	0.05		0.16	0.06	
A*B	0.63	0.09		9.54	1.02		0.22	0.01		0.28	0.11	
B*A	0.60	0.20		9.10	3.12		0.21	0.07		0.29	0.08	

Table 4: Effect of growth elicitors on yield parameters of gladiolus

Treatments	Number of spikes per hectare			Number of corms per hectare			Cormels yield per hectare (kg ha ⁻¹)		
	PS	PR	Mean	PS	PR	Mean	PS	PR	Mean
T ₁	1,82,750.0	1,80,166.7	1,81,458.3	1,95,402	1,95,673	1,95,538	450.06	432.88	441.47
T ₂	2,31,208.3	2,14,844.4	2,23,026.4	2,59,833	2,36,211	2,48,022	541.86	363.91	452.88
T ₃	2,15,691.7	2,94,902.8	2,55,297.2	2,45,654	3,50,414	2,98,034	776.60	457.14	616.87
T ₄	2,09,916.7	2,29,607.8	2,19,762.2	2,44,922	2,66,801	2,55,861	638.50	617.61	628.06
T ₅	2,51,666.7	2,29,000.0	2,40,333.3	2,83,920	2,53,716	2,68,818	732.88	753.98	743.43
T ₆	2,22,283.3	1,81,916.7	2,02,100.0	2,35,175	2,12,310	2,23,743	876.92	738.16	807.54
T ₇	2,05,300.0	2,15,333.3	2,10,316.7	2,13,854	2,41,591	2,27,722	824.36	509.92	667.14
T ₈	2,27,583.3	2,09,000.0	2,18,291.7	2,49,421	2,54,208	2,51,815	702.28	580.88	641.58
T ₉	2,24,500.0	2,32,416.7	2,28,458.3	2,55,922	2,60,813	2,58,368	683.48	601.83	642.66
T ₁₀	2,06,500.0	2,73,749.4	2,40,124.7	2,22,160	3,08,178	2,65,169	622.76	525.24	574.00
Mean	2,17,740.0	2,26,093.8		2,40,626	2,57,991		684.97	558.16	
	C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)		C. D. at 5%	S.Em (±)	
Var(A)	NS	1,942.96		14,744.46	2,250.66		45.25	6.91	
Trt(B)	28,517.65	9,902.52		27,979.12	9,715.51		39.79	13.82	
A*B	41,406.66	6,144.18		41,028.81	7,117.20		65.02	21.84	
B*A	39,699.66	13,426.94		39,499.31	13,227.61		65.83	19.78	

Note:

1. A*B-Treatment at same level of Variety.
2. B*A-Variety at same level of Treatment.
3. PS-Pusa Shanti
4. PR-Pusa Rajat

**Fig 1:** Maximum number of corms plant⁻¹ were found with treatment T₃ than control T₁ in Pusa Rajat



Fig 2: Maximum weight of corms plant⁻¹ were found with treatment T₆ and minimum weight recorded in T₁ in Pusa Shanti



Fig 3: Maximum rachis length was recorded with treatment T₃ and minimum recorded with T₇ in Pusa Shanti

4. Conclusion

The study found that benzyladenine (BA) at a concentration of 150 ppm was most effective in improving spike quality and corm production. In contrast, naphthaleneacetic acid (NAA) at concentrations between 300 and 450 ppm significantly enhanced cormel yield and floret longevity. Among the varieties examined, Pusa Rajat demonstrated superior spike and corm productivity, while Pusa Shanti excelled in vegetative growth and cormel yield. These differences in how each variety responds to growth regulators underscore the importance of optimizing genotype-specific strategies for maximizing gladiolus productivity and quality.

5. Future research

Future studies should validate the effectiveness of BA (150 ppm) and silicon (3%) under different agro-climatic conditions and seasons. The combined application of growth regulators and silicon should be explored to further improve growth, flowering, and corm production. More gladiolus cultivars should be evaluated to develop cultivar-specific recommendations. Studies on the physiological and biochemical effects of these treatments would help explain their mode of action. Economic feasibility and postharvest

performance should also be assessed to support their commercial adoption.

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