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Pratiksha Deepak Wakle
Department of Floriculture and Landscaping, VNMKV, Parbhani, Maharashtra, India

Vaishali V Bhagat
Associate Professor, College of Horticulture, VNMKV, Parbhani, Maharashtra, India

Sachin B Pavhane
Assistant Professor, College of Horticulture, VNMKV, Parbhani, Maharashtra, India

Anupama Vijay Rathod
Department of Floriculture and Landscaping, VNMKV, Parbhani, Maharashtra, India

Radha Kailas Pandit
Department of Floriculture and Landscaping, VNMKV, Parbhani, Maharashtra, India

Corresponding Author:
Pratiksha Deepak Wakle
Department of Floriculture and Landscaping, VNMKV, Parbhani, Maharashtra, India

Effect of plant growth regulators and pinching on growth and flower yield of crossandra (*Crossandra infundibuliformis* L. (Nees)

Pratiksha Deepak Wakle, Vaishali V Bhagat, Sachin B Pavhane, Anupama Vijay Rathod and Radha Kailas Pandit

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Abstract
The experiment was conducted in a Factorial Randomized Block Design with fifteen treatment combinations involving GA_3 (100 and 150 ppm), CCC (650 and 1000 ppm), and three levels of pinching (no pinching, single, and double pinching at 30 and 60 DAT), replicated twice. Results indicated that GA_3 @ 150 ppm without pinching (R2P0) produced maximum plant height, while GA_3 @ 150 ppm with double pinching (R2P2) enhanced branching, plant spread, stem thickness, leaf area, and flower yield (1.09 t/ha). The study highlights that the interaction between plant growth regulators and pinching significantly influenced growth and yield traits in crossandra.

Keywords: Plant growth regulators, crossandra, growth, yield, pinching

Introduction
Floriculture is an emerging alternative to traditional crops, offering higher returns and fulfilling cultural and social demands for flowers in India. Among various ornamental plants, Crossandra (*Crossandra infundibuliformis*), popularly known as the firecracker flower, holds great ornamental and cultural value, especially in southern states like Karnataka, Tamil Nadu, Andhra Pradesh, and Telangana. It is prized for its attractive orange blooms, long shelf life, and extensive use in garlands, decorations, and religious offerings (Chandana B, 2023) [3]

Crossandra, native to South India and Sri Lanka, belongs to the family Acanthaceae and is a perennial evergreen shrub with around 20-25 species, of which *C. infundibuliformis* is the most widely cultivated. The crop thrives in warm, humid climates, grows best in fertile red loam soils, and is propagated through seeds or cuttings. Despite its popularity, yield and quality remain low, demanding improved cultural practices (Bhattacharjee & De, 2003) [1].
Horticultural techniques such as pinching and the application of plant growth regulators (PGRs) are crucial for improving productivity. Pinching breaks apical dominance, promotes lateral branching, and increases flowering sites. Among PGRs, CCC (Cycocel) helps regulate plant height and improve flower quality, while GA_3 (Gibberellic Acid) enhances vegetative growth, flowering, and overall yield. Their combined use, integrated with pinching, can synergistically optimize growth, flower production, and commercial value of crossandra. Shreedhar and Sarvanan (2020) [10] and (Sharifuzzaman *et al.*, 2011) [9]
Thus, the present study entitled "Effect of Plant Growth Regulators and Pinching on Growth and Yield of Crossandra (*Crossandra infundibuliformis* (L.) Nees)" was undertaken to evaluate these practices under Parbhani conditions.

Materials and Methods
The experiment was conducted at the College of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, during the winter season of 2024-2025 (August to February). The trial was laid out in a factorial randomized block design (FRBD) with 15 treatment combinations and two replications. The crop variety used was *Arka Kanka* of family *Acanthaceae*. Each plot measured 3.0 × 2.4 m with spacing of 60 × 60 cm, accommodating 20 plants per plot.

Factor A (plant growth regulators) included five levels: control, GA_3 @ 100 ppm, GA_3 @ 150 ppm, CCC @ 650 ppm, and CCC @ 1000 ppm. Factor B (pinching) consisted of three levels: no pinching, single pinching at 30 DAT, and double pinching at 30 and 60 DAT. Thus, 15 treatment combinations were evaluated to study the individual and interactive effects of PGRs and pinching. Observations on growth, flowering, and yield were recorded at 30, 60, 90, and 120 days after transplanting.

Results and Discussion

Plant height was significantly influenced by plant growth regulators (PGRs) and pinching. During all stages of growth, maximum height was observed in plants without pinching and sprayed with GA_3 @ 150 ppm (75.30 cm at 120 DAT). Among interactions, R_2P_0 (GA_3 @ 150 ppm + no pinching) recorded significantly higher height (53.82 cm, 67.00 cm, 75.30 cm at 60, 90, and 120 DAT, respectively), while the lowest was in R_4P_2 (CCC @ 1000 ppm + double pinching). Double pinching consistently reduced plant height due to suppression of apical dominance, shifting assimilates towards lateral growth (Mohanty *et al.*, 2015) [4]. Similar dwarfing effects of CCC with pinching were reported in gaillardia by Moon *et al.* (2017) [5].

Branching was enhanced by both GA_3 and pinching. Maximum number of branches (26.98 at 120 DAT) was recorded in R_2P_2 (GA_3 @ 150 ppm + double pinching), while the lowest was in R_0P_0 (control + no pinching). The synergistic effect of GA_3, which promotes meristematic activity, and pinching, which suppresses apical dominance and activates axillary buds, resulted in improved branching. CCC also improved branching when combined with pinching, though less effectively than GA_3. These findings agree with Sahu *et al.* (2024) [8] in chrysanthemum.

Plant spread in both north-south and east-west directions was significantly higher with double pinching and GA_3 @ 150 ppm. At 120 DAT, R_2P_2 recorded maximum spread (38.9 cm N-S and 39.8 cm E-W), whereas R_0P_0 showed the lowest. GA_3 enhanced lateral shoot development and cell elongation, while pinching promoted canopy expansion. CCC acted as a growth inhibitor, limiting elongation but marginally supporting spread. Similar outcomes were reported in chrysanthemum and marigold (Sahu *et al.*, 2024; Mounika *et al.*, 2019) [8, 7].

Stem thickness was maximum in R_2P_2 (17.55 mm) and minimum in R_0P_0 (12.71 mm). GA_3 enhanced cell division and elongation, while pinching improved assimilate translocation, together contributing to thicker stems. Comparable results were reported in crossandra by Bose *et al.* (1980) [2]. Leaf area was also significantly increased with GA_3 and pinching. Maximum leaf area (2977.45 cm^2) was observed in R_2P_2, while minimum (1428.05 cm^2) was recorded in R_0P_0. GA_3 promoted cell enlargement, while pinching encouraged branching and canopy spread, leading to improved photosynthetic capacity.

Table 1: Effect of plant growth regulators, pinching, and their interaction on plant height, number of branches, plant spread, stem thickness, and leaf area of plants at different growth stages.

Treatment details	Plant height (cm)				Number of branches per plant				Plant spread n-s (cm)				Plant spread e-w (cm)				Stem thickness (mm)	Leaf area (cm^2)
	30 DAT	60 DAY	90 DAT	120 DAT	30 DAT	60 DAY	90 DAT	120 DAT	30 DAT	60 DAY	90 DAT	120 DAT	30 DAT	60 DAY	90 DAT	120 DAT		
Plant growth regulators																		
R_0	23.51	42.84	56.00	64.36	7.27	11.77	14.65	15.88	12.48	18.73	22.40	31.33	12.05	18.60	21.33	21.60	13.61	1450.30
R_1	23.39	47.01	56.53	70.60	7.59	16.97	21.55	23.72	12.53	23.30	29.60	35.13	12.32	22.73	26.83	34.47	16.21	2717.63
R_2	23.81	51.68	57.17	72.77	7.66	19.20	24.23	25.79	12.52	25.17	33.50	37.83	12.65	24.93	31.37	38.47	16.44	2914.72
R_3	23.60	34.35	51.30	66.53	7.34	14.97	17.83	20.50	12.15	19.90	23.50	32.73	12.45	19.90	21.48	28.97	15.03	2624.18
R_4	23.72	31.17	49.68	59.97	7.46	13.07	15.37	17.55	12.25	22.47	25.60	34.97	12.62	22.33	28.60	30.37	15.31	2768.55
SEm ±	0.23	1.27	0.13	0.23	0.15	0.14	0.14	0.12	0.12	0.63	0.65	0.33	0.15	0.33	0.45	0.26	0.12	18.19
CD @ 5%	NS	3.86	0.38	0.71	NS	0.44	0.44	0.37	NS	1.91	1.98	0.99	NS	0.99	1.37	0.78	0.37	55.16
Pinching																		
P_0	23.61	43.28	58.98	68.67	7.25	14.54	17.62	19.68	12.26	20.76	24.82	33.44	12.43	20.68	23.96	28.84	14.44	2446.72
P_1	23.69	41.63	52.90	66.51	7.50	15.30	18.54	20.38	12.36	21.90	27.22	34.22	12.43	21.86	25.77	30.94	15.11	2499.45
P_2	23.52	39.32	50.53	65.36	7.63	15.74	20.02	22.01	12.54	23.08	28.72	35.54	12.39	22.56	28.04	32.54	16.40	2539.05
SEm ±	0.18	0.99	0.10	0.18	0.12	0.11	0.11	0.09	0.10	0.49	0.51	0.25	0.12	0.25	0.35	0.20	0.09	14.09
CD @ 5%	NS	2.99	0.30	0.55	NS	0.34	0.34	0.29	NS	1.48	1.54	0.77	NS	0.77	1.06	0.61	0.29	42.73
Interaction																		
R_0P_0	23.3	45.41	61.40	65.54	7.00	11.50	13.30	15.20	12.2	19.5	18.8	29.4	11.9	17.7	19.2	20.0	12.71	1428.05
R_0P_1	23.82	43.8	54.90	64.16	7.30	11.90	14.30	15.60	12.4	18.2	24.0	31.4	12.1	19.0	21.0	21.0	13.35	1445.4
R_0P_2	23.4	39.32	51.70	63.39	7.50	11.90	16.35	16.95	12.85	18.5	24.0	33.2	12.15	19.1	23.8	23.8	14.78	1477.45
R_1P_0	23.54	48.89	58.50	72.10	7.66	16.50	19.90	22.80	12.45	22.9	28.8	34.3	12.25	22.1	25.2	33.2	15.45	2663.08
R_1P_1	23.37	46.92	57.60	70.20	7.45	16.80	21.60	23.50	12.5	23.3	29.4	35.2	12.3	22.8	26.8	34.5	15.98	2738.38
R_1P_2	23.25	45.21	53.50	69.50	7.65	17.60	23.15	24.85	12.65	23.7	30.6	35.9	12.4	23.3	28.5	35.7	17.21	2751.42
R_2P_0	23.68	53.82	67.00	75.30	7.50	18.10	23.40	24.90	12.5	22.2	31.8	37.1	12.6	23.5	29.8	36.9	15.66	2878.55
R_2P_1	23.92	51.55	53.30	72.20	7.55	19.60	24.10	25.50	12.6	26.5	33.5	37.5	12.65	24.7	31.0	38.7	16.10	2888.15
R_2P_2	23.82	49.67	51.20	70.80	7.93	19.90	25.20	26.98	12.45	26.8	35.2	38.9	12.7	26.6	33.3	39.8	17.55	2977.45
R_3P_0	23.64	36.68	55.70	68.20	6.70	14.10	16.60	18.50	12.1	17.1	20.6	32.0	12.75	19.2	19.3	27.0	14.22	2600.85
R_3P_1	23.79	34.61	48.80	66.40	7.85	14.90	17.50	20.00	12.0	20.7	24.3	32.8	12.55	19.9	21.25	29.2	14.79	2620.59
R_3P_2	23.38	31.75	49.40	65.00	7.46	15.90	19.40	23.00	12.35	21.9	25.6	33.4	12.05	20.6	23.9	30.7	16.07	2651.09
R_4P_0	23.89	31.6	52.30	62.20	7.40	12.50	14.90	17.10	12.05	22.1	24.1	34.4	12.65	20.9	26.3	27.1	14.18	2663.08
R_4P_1	23.53	31.25	49.88	59.60	7.37	13.30	15.20	17.30	12.3	20.8	24.9	34.2	12.55	22.9	28.8	31.3	15.35	2804.71
R_4P_2	23.73	30.65	46.85	58.10	7.60	13.40	16.00	18.25	12.4	24.5	27.8	36.3	12.65	23.2	30.7	32.7	16.40	2837.86
SE (m) ±	0.40	2.21	0.22	0.40	0.26	0.25	0.25	0.21	0.21	1.09	1.13	0.57	0.26	0.57	0.78	0.45	0.21	31.50
CD @ 5%	NS	6.69	0.66	1.23	NS	0.76	0.76	0.64	NS	3.31	3.43	1.71	NS	1.71	2.37	1.35	0.64	95.54

Treatment details	Number of flower per spike	Number of spike per plant	Yield per plant in g	Yield per plot in (kg)	Flower yield/ha (t)
Plant growth regulators					
R_0	38.40	62.67	178.25	3.57	0.50
R_1	47.83	68.73	314.77	6.30	0.87
R_2	50.35	70.72	368.56	7.37	1.02
R_3	42.15	66.02	250.11	5.00	0.69
R_4	45.63	67.35	261.47	5.23	0.73
SEm ±	0.20	0.28	2.65	0.05	0.01
CD @ 5%	0.60	0.85	8.03	0.16	0.02
Pinching					
P_0	43.92	66.28	257.42	5.15	0.72
P_1	44.74	66.89	279.79	5.60	0.78
P_2	45.96	68.12	286.69	5.74	0.80
SEm ±	0.15	0.22	2.05	0.04	0.01
CD @ 5%	0.47	0.66	6.22	0.13	0.02
Interaction					
R_0P_0	37.40	61.45	162.52	3.25	0.45
R_0P_1	38.50	62.10	180.73	3.61	0.5
R_0P_2	39.30	64.45	191.50	3.86	0.53
R_1P_0	47.50	68.25	300.15	6.00	0.83
R_1P_1	47.70	68.40	326.00	6.52	0.91
R_1P_2	48.30	69.55	318.16	6.36	0.88
R_2P_0	49.30	69.45	347.50	6.95	0.97
R_2P_1	49.50	70.45	365.05	7.30	1.01
R_2P_2	52.25	72.25	393.13	7.86	1.09
R_3P_0	40.90	65.25	235.50	4.71	0.65
R_3P_1	42.35	66.10	258.65	5.17	0.72
R_3P_2	43.20	66.70	256.18	5.12	0.71
R_4P_0	44.50	67.00	241.41	4.83	0.67
R_4P_1	45.65	67.40	268.50	5.37	0.75
R_4P_2	46.75	67.65	274.49	5.49	0.76
SE (m) ±	0.34	0.48	4.58	0.09	0.01
CD @ 5%	1.04	1.47	13.90	0.28	0.04

The number of flowers per spike was highest in R_2P_2 (52.25), while the lowest (37.40) was in R_0P_0. Double pinching with GA_3 @ 150 ppm proved most effective, showing the benefit of integrating cultural and chemical practices. Spikes per plant were maximum in R_2P_2 (72.25), while minimum yield was recorded in R_0P_0. GA_3 stimulated spike initiation, whereas pinching encouraged lateral shoots, thereby increasing spike numbers.

Flower yield per plant, plot and hectare were significantly influenced by treatments. Maximum yield per plant (393.13 g), per plot (7.86 kg), and per hectare (1.09 t) was observed in R_2P_2, while the lowest was recorded in R_0P_0. The combination of GA_3 150 ppm and double pinching enhanced photosynthetic efficiency, spike formation, and overall yield. Similar results were reported in chrysanthemum and gaillardia (Mounika *et al.*, 2019; Moon *et al.*, 2017) [7, 5].

Conclusion

GA_3 @ 150 ppm with double pinching was most effective in improving plant growth, branching, spread, and overall flower yield in crossandra, whereas no pinching favored taller plants.

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