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Effect of growth regulators on growth, flowering and yield of Crossandra (*Crossandra undulaefolia* Salisb)

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Abstract
An investigation was undertaken to study the effect of growth regulators on growth and flowering of crossandra (*Crossandra undulaefolia* Salisb) genotype *Arabhavi crossandra* collection-1(ACC-1) at the Department of Floriculture and Landscape Architecture, Kittur Rani Channamma College of Horticulture, Arabhavi, University of Horticultural Sciences, Bagalkot, during *kharif* and *rabi* season from June, 2015 to February, 2016. The plants were given treatments of two concentrations of Gibberellic acid (100 and 200 ppm), NAA (100 and 150 ppm), TIBA (100 and 150 ppm), Ethrel (50 and 100 ppm) and one control (water spray). Altogether there were nine treatments and were replicated thrice. The plant growth regulators were sprayed four times *viz.*, 15, 30, 45 and 60 days after transplanting. All the treatments of growth substances registered significant effect on growth, development and flowering of crossandra. However, the plants sprayed with the Gibberellic acid (200 ppm) resulted in maximum plant height (71.10 cm), leaf area (3337.83 cm^2), dry matter (88.85g), number of branches (17.63), plant spread (46.19 cm), days taken to flower spike initiation (38.00), days taken to first harvest (53.00), duration of flowering (131.00) and flower yield per plant (82.60g).

Keywords: Crossandra, growth regulators, Gibberellic acid, *Crossandra undulaefolia*, flowering and yield.

Introduction
Crossandra is an important commercial crop grown mainly in India, Tropical Africa and Madagascar (Bailey, 1963) [3]. Crossandra is an important loose flower in South India and commercially grown to an extent of 4,000 ha in Karnataka, Tamil Nadu and Andhra Pradesh (Bhattacharjee, 2006) [4] which was increased to 4700 ha during 2014-15 (Anon., 2014) [2]. Crossandra belongs to the family Acanthaceae. There are around 50 species but only a few species like *Crossandra undulaefolia* Salisb. (Syn: *Crossandra infundibuliformis* (L.) Nees.), *Crossandra mucronata* and *Crossandra sebacaulis* are cultivated. The species grown for commercial flower production is *Crossandra undulaefolia* Salisb. Crossandra is a perennial evergreen herb or under-shrub in habitat. In recent years, the use of growth regulators in floriculture crop production has undergone enormous change to enhance the yield. These plant growth regulators play an important role in plant growth modification and development process. Although, endogenous growth substances normally regulate the plant growth, exogenous application of plant growth substances bring out modification in growth and development. Hence, the proposed research programme helps the farmers in choosing specific concentration of growth regulator on genotype ACC-1 to increase flower yield.

Materials and Methods
The experiment was conducted during June 2015 to February 2016 at experimental field of Department of Floriculture and Landscape Architecture, Kittur Rani Channamma College of Horticulture, Arabhavi (University of Horticultural sciences, Bagalkot, Karnataka). The cuttings of various collections of length 10-15 cm were raised in pots during first week of June 2015. For better root development IBA- 3000 ppm for 30 minutes was used. The vegetative cuttings were ready for transplanting after 70 days. The transplanting was done during first week of August 2015 in kharif season. Irrigation was given after the planting.

The experiment was laid out by using factorial randomized complete block design (RCBD) with nine growth regulator treatments and three replications. The plants were given treatments of two concentrations of Gibberellic acid (100 and 200 ppm), NAA (100 and 150 ppm), TIBA (100 and 150 ppm), Ethrel (50 and 100 ppm) and control (water spray). The plant growth regulators were sprayed four times *viz.*, 15, 30, 45 and 60 days after transplanting. The quantity of growth regulators required for investigation was dissolved in 1000 ml of distilled water. The growth regulators α-Naphthalene acetic acid (NAA) and TIBA was dissolved in two to three pellets of sodium hydroxide solution and final volume was made up to 1000 ml of distilled water, whereas Gibberellic acid (GA_3) and ethrel was directly dissolved in distilled water. All observations were taken at 30, 60, 90, 120, 150 and 180 days after transplanting (DAT). Five plants were randomly selected and tagged for recording observations on growth, development, flowering parameters and flower yield. The data on various biometrical parameters recorded during the period of investigation was tabulated and subjected to statistical analysis using factorial randomized complete block design (RCBD). The test of significance ('f' test) and critical difference (CD) were read at 0.05 probabilities (Sunderaraju *et al.*, 1972) [18].

Results and Discussion

Growth parameters

The data on plant height, leaf area and dry matter was presented in table 1. In the present study there were significant differences for plant height with different growth promoter treatments at different growth stages of crossandra. At 30 days after transplanting (DAT), the plant height was found to be non-significant which was varies from 28.11 to 30.43 cm. At 60 DAT, among the different treatments plant height varied from 33.93 cm to 41.53cm. The treatment GA_3 at 200 ppm (T_2) showed highest plant height (41.53 cm) which was on far with GA_3 at 100 ppm (T_1), NAA @100 ppm (T_3), the lowest plant height (33.93 cm) was found in control. At 90 DAT stage, the plant height was observed in the range of 38.03 cm to 56.00 cm. Among the treatment, the treatment GA_3 at 200 ppm (T_2) was recorded tallest with a plant height of 56.00 cm. The plant height was minimum (38.03 cm) in control (T_9). At 120 DAT the plant height was maximum (62.80 cm) in treatment GA_3 at 200 ppm (T_2) and treatment nine (control) showed minimum plant height (41.43 cm). At 150 DAT stage the plant height range was 46.83 cm to 69.50 cm. Among the treatment, GA_3 at 200 ppm (T_2) was recorded highest with a plant height of 69.50 cm. The minimum plant height was recorded in control (46.83 cm). At 180 DAT the plant height was highest (71.10 cm) in treatment GA_3 at 200 ppm and it was minimum in the treatment T_9 (48.61cm). The application of GA_3 at 200 ppm alone produced maximum plant height at all stages of growth. Wherein, GA which is growth promoters might have helped in accelerating cell division and enlargement as reported by Mandava (1988) [12]. These results are in confirmation with that of Binisundar *et al*. (2008) [5] in crossandra. The enhanced cell division, cell enlargement and promotion of protein synthesis by GA application exogenously, might have resulted in enhanced vegetative growth as reported by Girish *et al.* (2012) [9] in daisy.

Significantly higher leaf area per plant (3337.83 cm^2) was recorded in treatment GA_3 at 200 ppm and the minimum leaf area was recorded in treatment control (1590.84cm^2). Leaf area was significantly influenced by growth promoters at different stages of plant growth. The leaf area was maximum in GA followed by TIBA. Similarly, Binisundar *et al.* (2008) [5] observed maximum leaf area in plants sprayed with GA_3 200 ppm. The increase in leaf area might be due to production of more number of leaves of maximum length and leaf width as reported by Nandre *et al.* (2009) [13] in china aster and Sharma *et al.* (2006) [15] in gladiolus. The maximum dry matter (88.85 g) was showed in treatment GA_3 at 200 ppm (T_2). The treatment NAA at 100 ppm (38.59 g) was showed minimum dry matter of whole plant. Profuse dry matter was produced in the plants sprayed with the application of GA at lower concentrations. Whereas, lowest dry matter production was noticed in control plants. It is due to the fact that the plants treated with GA had increased leaf area which might have facilitated the accumulation of more carbohydrates in terms of increased dry matter production. Maximum dry matter production was recorded in crossandra reported by Binisundar *et al.* (2008) [5] and Nandre *et al.* (2009) [13] in China aster.

Table 1: Influence of different plant growth regulators on plant height (cm) at different stages of crop growth, leaf area and dry matter.

Treatment details	Plant height (cm) at different DAT						Leaf area (cm^2)	Dry matter (g)
	30	60	90	120	150	180		
T_1- GA_3 @ 100 ppm	30.00	40.23	51.24	57.77	62.90	64.60	2760.40	73.40
T_2- GA_3 @200 ppm	30.43	41.53	56.00	62.80	69.50	71.10	3337.83	88.85
T_3-NAA @100 ppm	28.32	37.53	44.36	49.47	53.77	55.04	1762.34	38.59
T_4-NAA @150 ppm	28.11	36.07	39.07	43.17	50.03	51.44	1853.49	44.14
T_5-TIBA @100 ppm	29.37	38.20	42.93	46.13	49.40	50.60	1810.68	42.66
T_6-TIBA @150 ppm	28.29	39.80	41.23	45.73	50.63	52.43	1796.59	53.92
T_7- Ethrel @50 ppm	28.20	34.69	40.33	45.93	50.20	52.63	1645.93	50.00
T_8-Ethrel @100 ppm	28.54	35.37	40.67	46.67	50.27	51.57	1688.72	50.07
T_9-Control.	29.15	33.93	38.03	41.43	46.83	48.61	1590.84	42.50
S. Em (±)	0.87	1.54	1.43	1.06	1.13	1.09	139.21	3.44
CD at 5 %	NS	4.62	4.29	3.20	3.41	3.28	417.63	10.32

DAT: Days after transplanting**; NS:** Non-significant

Data pertaining to number of branches produced per plant and plant spread North-South for different treatment is presented in Table 2. Number of branches at 30 DAT (days after transplanting) found to be significantly differing from all the treatments. Maximum number of branches (3.81) was recorded in the treatment GA_3 at 200 ppm which was on par with GA_3 at 100 ppm (3.53). The lowest number of branches (2.59) was recorded in treatment T_9 (control). Number of branches per plant at 60 DAT found to be maximum (6.47) in treatment GA_3 at 200 ppm (T_2) and the lowest (4.40) was observed in control. The genotype varied significantly for the trait number of branches at 90 DAT and the highest number

of branches was recorded in GA_3 at 200 ppm (11.20) and control (8.03) recorded lowest number of branches. At 120 DAT The treatment GA_3 at 200 ppm recorded highest number (14.40) of branches per plant, which was on par with GA_3 at 100 ppm (14.20) and TIBA at 150 ppm (13.03) whereas, control (T_9) recorded lowest number of branches per plant (12.00). At 150 DAT the number of branches per plant was highest (16.97) in T_2 (GA_3 at 200 ppm). The treatment control showed minimum number of branches per plant (14.13). At 180 days DAT the number of branches per plant was highest (17.63) in GA_3 at 200 ppm and control recorded minimum number of branches per plant (14.78). Maximum number of branches was recorded in application of GA and NAA (200 ppm). Stimulation of branching may be attributed to the breakage of apical dominance. Similar results were reported by Binisundar *et al*. (2008) [5] in crossandra, Lal and Mishra (1986) [11] in aster and marigold, Shetty (1995) [16] and Doddagoudar *et al.* (2002) [7] in China aster and. Padmapriya and Chezhiyan (2003) [14] in chrysanthemum and Amit *et al*. (2011) [1] in African marigold.

Table 2. Influence of different plant growth regulators on number of branches per plant and plant spread North-South at different stages of crop growth

Treatment details	Number of branches/plant at different DAT						Plant spread North – South (cm) at different DAT					
	30	60	90	120	150	180	30	60	90	120	150	180
T_1- GA_3 @ 100 ppm	3.53	5.93	9.83	14.20	16.17	16.83	21.43	24.46	27.30	30.36	37.36	44.15
T_2- GA_3 @200 ppm	3.81	6.47	11.20	14.40	16.97	17.63	22.40	25.23	28.13	32.78	40.44	46.19
T_3-NAA @100 ppm	3.43	5.60	9.40	12.57	15.57	16.37	21.03	23.57	26.30	29.24	36.83	42.94
T_4-NAA @150 ppm	3.21	5.50	8.37	12.48	14.33	15.05	20.93	23.73	26.40	28.28	35.82	42.16
T_5-TIBA @100 ppm	3.17	5.10	9.03	12.93	14.33	15.04	20.88	23.53	26.17	27.82	35.62	41.45
T_6-TIBA @150 ppm	3.12	5.13	9.20	13.03	15.07	15.70	20.37	23.70	26.23	28.09	35.76	41.15
T_7- Ethrel @50 ppm	2.85	5.10	8.73	12.13	14.71	15.46	20.83	22.31	25.53	27.19	35.39	41.48
T_8-Ethrel @100 ppm	2.85	4.97	8.30	12.60	14.73	15.48	20.50	22.50	25.40	27.40	35.17	40.88
T_9-Control.	2.59	4.40	8.03	12.00	14.13	14.78	20.90	22.10	24.00	26.84	32.50	37.53
S. Em (±)	0.10	0.12	0.20	0.48	0.19	0.19	0.37	0.39	0.49	0.58	0.72	0.54
CD at 5 %	0.31	0.37	0.61	1.46	0.59	0.57	NS	1.18	1.48	1.76	2.18	1.63

DAT: Days after transplanting**; NS:** Non-significant

The plant spread North-South at 30 DAT was found to be non-significant which varies from 20.37 to 22.40 cm. The treatment differed significantly for plant spread at 60 DAT and it was observed in the range 22.10 cm to 25.23 cm. The treatment GA_3 at 200 ppm (T_2) continued to grow with a widest canopy of 25.23 cm spread, which was on far with GA_3 at 100 ppm (24.46 cm). The least plant spread (22.10 cm) was observed in control (T_9). At 90 DAT the treatment GA_3 at 200 ppm had the maximum plant spread (28.13 cm), which was on far with GA_3 at 100 ppm (27.30 cm). The least plant spread (24 cm) was observed in control (T_9). At 120 DAT GA_3 at 200 ppm (32.78 cm) had the maximum plant spread. The least plant spread (26.84 cm) was observed in control (T_9). There was significant difference in the plant spread among the treatment at 150 days after transplanting. Plant spread was recorded in the range of 32.50 cm to 40.44 cm. The treatment GA_3 at 200 ppm (T_2) had the maximum plant spread (40.44 cm). The least plant spread (32.50 cm) was observed in control (T_9). At 180 DAT plant spread was recorded in the range of 37.53 cm to 46.19 cm. The treatment GA_3 at 200 ppm (T_2) recorded maximum plant spread (46.19 cm) and the least plant spread (37.53 cm) was observed in control (T_9). Maximum plant spread was recorded in application of GA (200 ppm). GA is known to influence the cell elongation, enlargement primary and secondary branches (vegetative growth) which in turn influence the plant spread (Kulkarni and Reddy, 2003) [10]. Similar findings were noticed by Shinde *et al.* (2010) [17] in chrysanthemum. Gautam *et al.* (2006) [8] in chrysanthemum.

Flowering parameters and flower yield

Data pertaining to flowering parameters like days taken to first flower spike initiation, days taken to first harvest and duration of flowering are furnished in Table 3. Treatments differ significantly for the days required to first flower spike initiation. The treatment GA_3 at 200 ppm (T_2) was early to show its visible flower spike in 38.00 days after transplanting, which was on par with GA_3 at 100 ppm (40.67 days), ethrel at 50 ppm (42.33 days) and ethrel at 100 ppm (T_8) (42.67 days). The treatment control (T_9) (46.00 days) was late to initiate flower spike. The treatments differ significantly for days taken to first harvest. The treatment GA_3 at 200 ppm (T_2) was early to harvest in 53.00 days after transplanting and control (T_9) shown late to harvest the flowers (61.95 days). Results revealed that the significant variation among the different growth regulator treatments for duration of flowering. Flower duration period was maximum in the treatment GA_3 at 200 ppm (131 days) and it was minimum in control (112 days).

Flower yield per plant showed significant and it was found maximum in GA_3 @200 ppm treatment (82.60g/plant) followed by GA_3 @100 ppm (78.43g/plant) and it was lowest in control (70.31g/plant). In general the plants treated with GA were early to produce first flower than control plants. This might be due the effect of gibberellins, as gibberellins influences florigen which requires for formation of flowers which leads to early harvesting of flowers and enhance flowering duration. These results are in accordance with Binisundar *et al*. (2008) [5] in crossandra, Girish *et al*. (2012) [9] in daisy and Doddagoudar *et al*. (2004) [6] in China aster.

Table 3: Influence of different plant growth regulators on flower spike initiation, days taken to first harvest and duration of flowering.

Treatment details	Days to flower spike initiation	Days taken to first harvest	Duration of flowering	Flower yield per plant (g)
T_1- GA_3 @ 100 ppm	40.67	55.67	122.67	78.43
T_2- GA_3 @200 ppm	38.00	53.00	131.00	82.60
T_3-NAA @100 ppm	45.33	60.33	121.33	72.61
T_4-NAA @150 ppm	45.10	60.40	117.33	72.96
T_5-TIBA @100 ppm	44.67	59.67	117.67	71.54
T_6-TIBA @150 ppm	45.67	60.33	119.33	71.00
T_7- Ethrel @50 ppm	42.33	57.33	117.67	70.60
T_8-Ethrel @100 ppm	42.67	57.67	119.33	70.75
T_9-Control	46.00	61.95	112.00	70.31
S. Em (±)	1.63	0.09	1.94	1.37
CD at 5 %	4.89	0.27	5.82	4.12

Conclusion

From the results of investigation it was concluded that the plants sprayed with GA_3 at 200 ppm improves the growth, development and flower yield of crossandra genotype ACC-1 and this growth regulator was evolved as suitable growth regulators in order to get more yield with good quality flowers.

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