International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(6): 1560-1567

Received: 13-09-2020
Accepted: 23-10-2020

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Studies on effect of plant growth regulators on plant growth and flower yield of crossandra (*Crossandra infundibuliformis L.*) var. Arka ambara

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DOI: https://doi.org/10.22271/chemi.2020.v8.i6v.10989

Abstract
The field experiment was conducted to determine "Effect of Plant Growth Regulators on Growth and Flower Yield of Crossandra (*Crossandra infundibuliformis* L.) cv. Arka Ambara" under Prayagraj agro-climatic conditions in the Department of Horticulture, SHUATS, Prayagraj, (U.P) during the Kharif season 2019-20. The experiment was laid out in Randomized Block Design with 13 treatments replicated thrice. The treatments were comprised of three concentrations of Gibberellic acid (50,100,150 ppm), NAA (50,100,150 ppm), Cycocel (500,750, 1000 ppm), Maleic Hydrazide (100,200,300 ppm) and control (water spray). The plant growth regulators were sprayed four times viz., 30, 60, 90 and 120 days after transplanting. The result revealed that T_7(GA_3@150ppm) was recorded maximum plant height (71.10) and minimum in CCC @1000ppm T_{10}(48.61).Significantly maximum leaf area (2987.67 cm^2), number of branches(16.23),duration of flowering (128 days),number of flowers per spike (51.45), flower yield per plant (82.60 g), flower yield per hectare (4.23 t/ha), shelf life (3.64 days) were also observed in plants sprayed with the Gibberellic acid @150ppm similarly minimum was observed with T_0 control and days taken to flower spike initiation T_6 (35.23days) observed at GA_3 @100 ppm significantly early to harvest and maximum flower weight (4.24 g) /100 flower was observed. The results shows that significant difference among the different plant growth regulators with respect to growth parameters, which are responsible for flower yield.

Keywords: crossandra, plant growth regulators (GA_3, NAA, cycocel and maleic hydrazide), flowering and yield

Introduction
Crossandra (Crossandra infundibuliformis L.) is commonly known as 'Fire cracker plant'. Crossandra is an evergreen shrub belonging to the family Acanthaceae. The family contains mainly herbaceous plants but also contain shrubs as well as few small trees. This is a large family of about 200 genera containing 2000 species. Many of the species are cultivated in garden because of their beautiful coloured flowers. It consists of five cultivars namely orange, yellow, red, deep orange and bluish flowered forms. It grows to about 3 feet height, with upright growth habit. The leaves are toothed, verticillate hairy or glabrous. The flowers are non-fragrant. The inflorescence is a dense sessile spike with predominant bracts. The scarlet orange flowers are borne on four sided spikes; stamens are four in number, capsule is oblong, acute and contains four seeds.

Two types of crossandra commercially cultivated, they are: (i) Orange Crossandra (2n=40), a tetraploid which sets seeds profusely, breeds true to type and produces bright orange coloured flowers and (ii) Delhi crossandra, triploid (2n=30) which produces more attractive flowers of bright deep orange colour and is propagated through stem cuttings. All species of crossandra are native of the Arabian Peninsula, tropical Africa, Madagascar, India and Sri Lanka. Being an important commercial flower, it is mainly grown in India, tropical Africa and Madagascar. It is an important group of flowering plants cultivated on a commercial scale and is being grown extensively in Southern states of India. It is known as Kanakambara in Karnataka and it is grown to an extent of 4,000 ha in Karnataka, Tamil Nadu and Andhra Pradesh (Bhattacharjee, 2006) which was increased to 6400 ha during 2018-19 (Demok., 2018).

The flowers of crossandra are commercially used for garlands making, as hair adornment and performing religious and ceremonial functions. The flowers are offered to temple deities. Though the flowers are non-fragrant like jasmine, rose or tuberose, they are priced high for their attractive bright colour, shelf life, light weight likewise the flowers are especially valued for making garlands, either alone or in combination with jasmine flowers and mostly used in making gajras and venis. Crossandra consists of five coloured forms namely orange, yellow, red, deep orange and bluish flowered forms. But it is highly susceptible to wilt, root knot and lesion nematodes. The cultivars with orange coloured flowers are generally preferred for commercial cultivation. The plants are quite hardy and can be grown for flowerbeds and /or cultivated for loose flowers.

The word crossandra is derived from Greek words 'krossoi' meaning fringe and 'aner' meaning male, thus word crossandra means fringed stamens. It does not have fragrant flowers but it is still desired for its distinct and attractive colour that has attracted the heart of every human being. The firecracker flower, relatively known to the general public as a houseplant. This flower is also a valuable ornamental pot flower in Sweden, Denmark and Hungary (Ottosen and Christensen, 1986)

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. They are known to bring various changes in plants. These in minute concentrations can dramatically change the plants vegetative and reproductive parameters.

Growth promoters not only alter the growth parameters, advance blooming, promotes flowering in many ornamental plants but also extend the shelf-life of many cut flowers. These growth substances improve the physiological efficiency of the plants by regulating the rate of photosynthesis, transpiration, photorespiration, water and nutrient uptake, leaf senescence and by imparting resistance to environmental stresses and ultimately increasing the harvest index. It is generally accepted that exogenously applied growth substances show their effects through the alteration in the levels of naturally occurring hormones and it varies with their concentrations used, method of application and frequency of application on plants, species, varieties and various other factors which influence the absorption and translocation of the chemicals, thus modifying the growth and development of plants.

The commercial cultivation of crossandra depends on many factors like climatic condition, fertilizer application, spacing, etc. Among them application of growth regulators is also one of the important factor to get higher yield. So, there is need to study the effect of growth regulators on growth and yield of crossandra.

The commercial field growing crossandra thrives well under sub-tropical climatic conditions with cultural operations like proper spacing and application of proper dosage of manures and fertilizers. Hence, the proposed research programme helps the farmers in choosing specific concentration of growth regulator on the variety of Arka Ambara to increase flower yield.

Materials and Methods

The present study entitled "Effect of Plant Growth Regulators on Growth and Flower Yield of Crossandra (*Crossandra infundibuliformis* L.) cv. Arka Ambara" under Prayagraj agro-climatic conditions in the Department of Horticulture, SHUATS, Prayagraj, (U.P) during the Kharif season 2019-20. The detail of the experiment site, soil, climate is described in this chapter together with the experimental design, plan layout, culture practice and techniques employed for growth studies.

Location

The experiment was conducted at Horticulture research farm SHUATS Prayagraj in 2019-20

Experimental Site

Which is located at 250271N latitutde, 81051lE longitude and 98m above the mean sea level. Climatic condition –Extremely hot summer and fairly cold winter, the temperature ranges from 35-48 degree centigrade and RH ranges between 20-94%. The average rainfall is around 850-1100mm annually.

Details of Treatment

Plant growth regulator

There were 13 treatments 3 replications, it comprising of different growth regulators viz., Gibberellic acid (50,100,150 ppm), NAA (50,100,150 ppm), Cycocel (500,750, 1000 ppm), Maleic Hydrazide (100,200,300 ppm) and control (water spray). The experiment was laid out in the Randomized Block Design (RBD) with 13 treatment and three replications. The Rooted cuttings were planted at 60 cm × 40 cm spacing in unit plot of 1m × 1 m. The crop was fertilized with 100 kg/ha of urea, 60 kg/ha of MPO and 60 kg/ha of SSP (as per standard recommendation), intercultural operations like weeding, earthing up and watering were done as and when necessary. The observations were recorded with respect to growth parameters at 30, 60, 90 120 and150 DAP to know the response of crossandra to different growth regulators at different concentration

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 DAT, the plant height was non-significant which was varies from 25.82 to 30 cm. At 60 DAT, among the different treatments plant height varied from 32.1 cm to 40.38 cm. The treatment GA_3 at 150 ppm (T7) showed the highest plant height (40.38 cm). The lowest plant height (32.10 cm) was found in CCC @ 1000 ppm (T10). At 90 DAT stage, the plant height was observed in the range of 36.07 cm to 52.96 cm. Among the treatment, the treatment GA_3 at 150 ppm (T7) was recorded tallest with a plant height of 52.96 cm. The plant height was minimum (36.07 cm) in CCC @ 1000 ppm (T10). At 120 days after transplanting the plant height varied from 39.64 to 59.54 and was maximum (59.54 cm) in treatment GA_3 at 150 ppm (T7). The treatment CCC @ 1000 ppm (T10) showed minimum plant height (39.64 cm). At the 150 DAT stage, the plant height was observed in the range of 44.52 cm to 65.38 cm. Among the treatment, T7 recorded the highest plant height of 65.38 cm. The minimum plant height was

recorded in T10 (44.52 cm). At 180 days after transplanting the plant, height was again highest (67.01 cm) in treatment T7 and minimum in treatment T10 (46.56 cm). In the present study, there were significant differences for plant height with different growth promoter treatments at different growth stages of crossandra. The application of GA3 at 150 ppm alone produced maximum plant height. Wherein, GA which is growth promoters might have helped in accelerating cell division and enlargement as reported by Mandava (1988) [11] these results are in confirmation with that of Binisundar *et al.* (2008) 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 (2012) [8] in daisy.

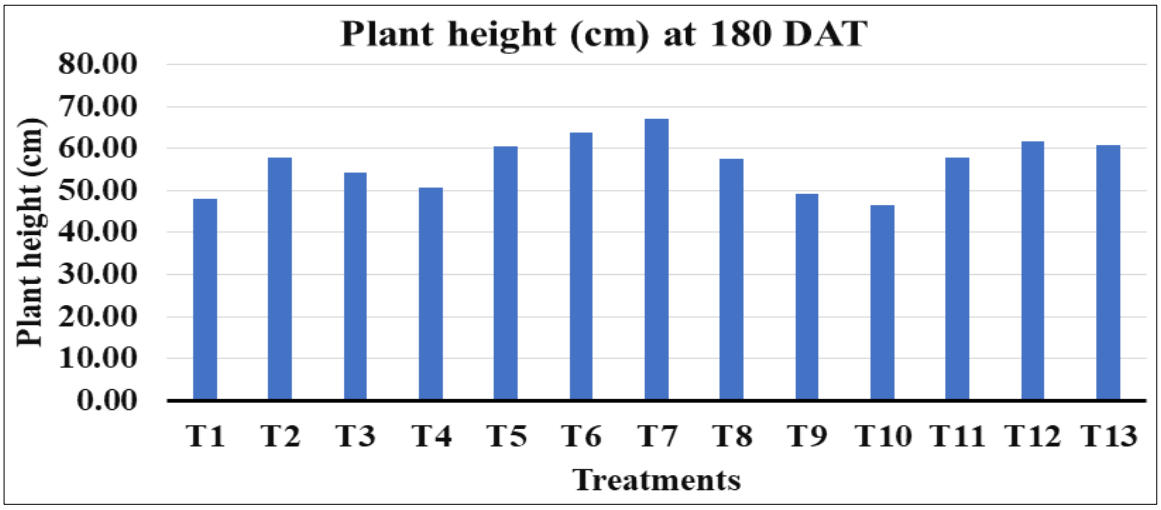
The character of stem girth among the different treatments, GA_3 at 150 ppm (T7) had the maximum stem girth (14.26 mm), whereas control (12.44 mm) recorded minimum stem girth. The stem girth varied significantly for different growth promoters in all crop stages. Thick stem girth was in GA_3 treated plants, followed by plants treated with MH and CCC. Whereas, thinnest stem girth was observed in control. Stem girth was found to be maximum in GA because GA is known to influence cell enlargement and cell division. Similar results were observed by Gautam *et al.* (2006) [7] in chrysanthemum and Bhattacharjee *et al.* (1984) in dahlia.

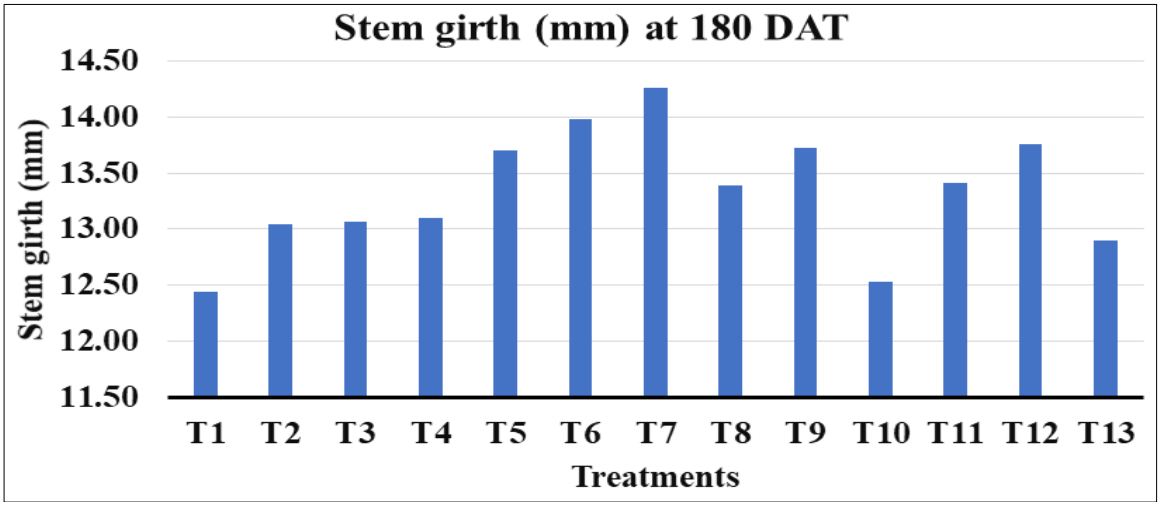
A significant difference was observed among the treatment. The leaf area was maximum (3011.47 cm^2) in treatment GA3 at 150 ppm and the minimum leaf area was recorded in treatment control (1571.20 cm^2). Leaf area was significantly influenced by growth promoters at different stages of plant growth. The leaf area was maximum in GA followed by CCC and MH. Similarly, Binisundar *et al.* (2008) observed maximum leaf area in plants sprayed with GA3 200 ppm. The increase in leaf area might be due to the production of more leaves of maximum length and leaf width as reported by Nandre *et al.* (2009) [12] in China aster and Sharma *et al.* (2006) [14] in gladiolus.

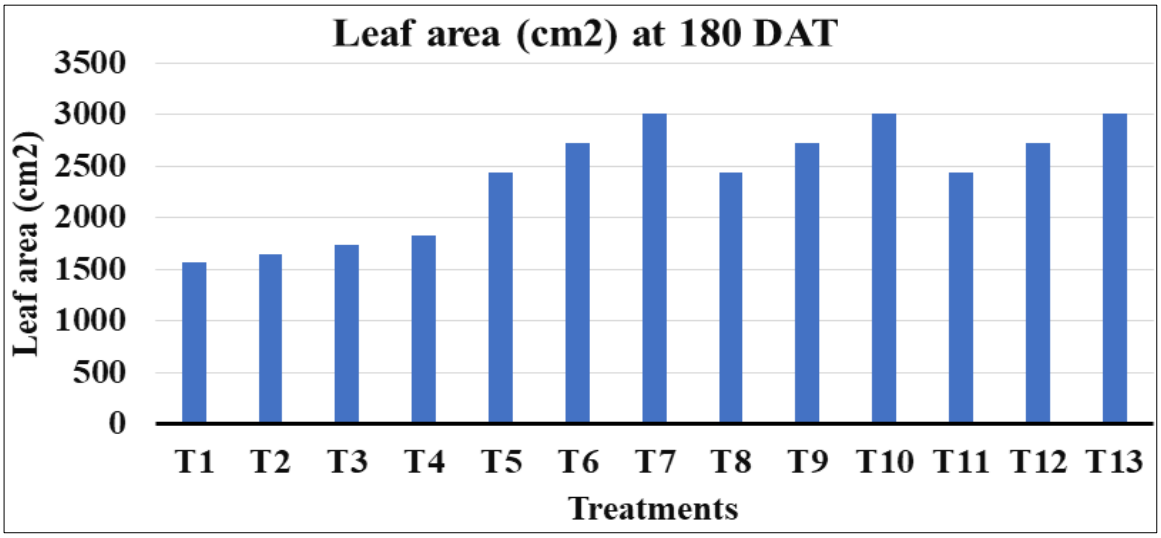
The maximum dry matter in the treatment GA3 at 150 ppm (T7) was showed maximum dry matter (80.12 g). The treatment NAA at 50 ppm (32.62 g) yielded the minimum dry matter of the whole plant. A significant influence on dry matter production by different growth promoters in all crop stages was observed. Profuse dry matter was produced in the plants sprayed with the application of GA at lower concentrations. Whereas, lower dry matter production was noticed in control plants. It is because 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) and Nandre *et al.* (2009) [12] in China aster.

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

Treatment details	Plant height (cm) at different DAT						Stem girth(cm^2)	Leaf area (cm^2)	Dry matter(g)
	30	60	90	120	150	180			
T1 - CONTROL	28.79	33.51	37.56	40.92	46.25	48.01	12.44	1571.2	41.98
T2 - NAA @ 50 ppm	28.18	38.52	49.03	55.08	56.81	57.92	13.04	1650.55	32.62
T3 - NAA @ 100 ppm	27.97	37.07	43.81	48.86	53.11	54.36	13.07	1740.58	38.11
T4 - NAA @ 150 ppm	27.76	35.62	38.59	42.64	49.41	50.80	13.10	1830.61	43.6
T5 - GA3 @ 50 ppm	29.42	39.09	48.26	54.58	58.86	60.59	13.71	2441.17	64.86
T6 - GA3 @ 100 ppm	29.63	39.73	50.61	57.06	62.12	63.80	13.98	2726.32	72.49
T7 - GA3 @ 150 ppm	29.84	40.38	52.96	59.54	65.38	67.01	14.26	3011.47	80.12
T8 - CCC @ 500 ppm	26.62	35.69	45.66	51.48	56.46	57.49	13.40	2438.37	61.46
T9 - CCC @ 750 ppm	30.00	34.64	38.61	42.17	47.37	49.09	13.72	2723.72	69.29
T10 - CCC @ 1000 ppm	27.31	32.10	36.07	39.64	44.52	46.56	12.53	3009.07	77.12
T11 - MH @ 100 ppm	25.82	36.39	45.36	51.08	55.46	57.69	13.42	2437.57	62.16
T12 - MH @ 200 ppm	26.33	36.93	47.81	53.36	59.92	61.60	13.76	2723.02	69.69
T13 - MH @ 300 ppm	26.84	37.48	50.26	55.64	59.72	60.88	12.90	3008.47	77.22
S. Em (+)	0.85	1.52	1.37	1.15	1.06	1.22	0.21	213.21	3.69
CD at 5 %	NS	4.66	4.19	3.47	3.21	3.51	0.68	512.32	11.34







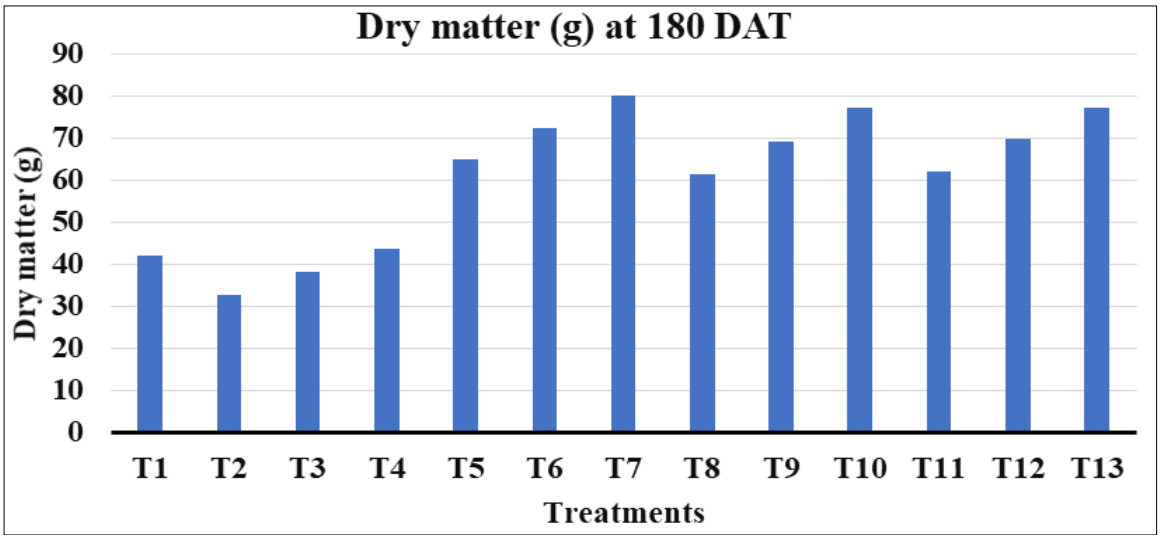


Fig 1: Influence of different plant growth regulators on dry matter(g)

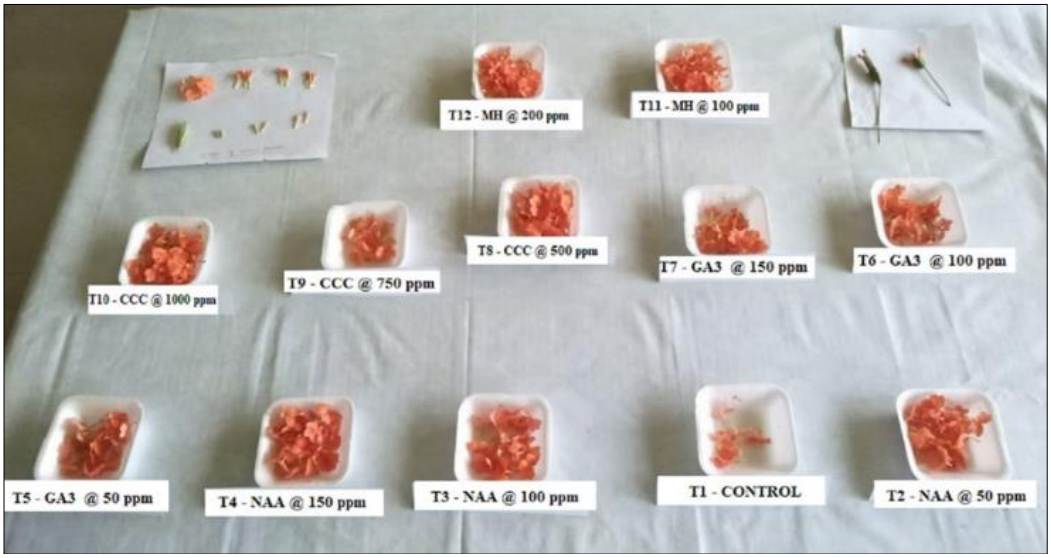


Fig 2: Lab display of all treatment samples of harvested flowers

Fig 3: Lab display

Fig 4: Treatment wise harvested flowers are displayed at lab and observed by Advisor Dr. S S Saravanan

Fig 5: Stages of flower growth

The data pertaining to number of branches produced per plant for different treatment is presented in table 2. The number of branches at 30 days after transplanting was found to be significantly differing for all the treatments. Maximum number of branches (3.63) was recorded in the treatment GA3

at 150 ppm. The lowest number of branches (2.56) was recorded in treatment T1 (control).

The number of branches per plant at 60 days after transplanting varied significantly among the growth regulator treatments. It was found to be maximum (6.13) in treatment GA3 at 150 ppm (T7) ant the lowest (4.35) was observed in control. The highest number of branches 90 days after transplanting was recorded in GA3 at 150 ppm (10.39) and control (7.93) recorded the lowest number of branches.

The number of branches per plant at 120 days after transplanting varied significantly among the treatment. The treatment GA3 at 150 ppm recorded the highest number (14.12) of branches per plant whereas, control (T1) recorded the lowest number of branches per plant (11.85). At 150 days after transplanting the number of branches per plant was highest (16.61) in T7 (GA3 at 150 ppm). The treatment control showed the minimum number of branches per plant (13.96). At 180 days after transplanting the number of branches per plant was highest (17.48) in GA3 at 150 ppm and control recorded the minimum number of branches per plant (14.60). The maximum number of branches was recorded in the application of GA (150 ppm). Stimulation of branching may be attributed to the breakage of apical dominance. Similar results were reported by Binisundar et.al. (2008) in crossandra, Lal and Mishra (1986) in aster and marigold, Shetty (1995) [15] and Doddagoudar (2002) [5] in China aster and Padmapriya and Chezhiyan (2003) [13] in chrysanthemum and Amit *et al*. (2011) in African marigold.

Plant spread

The plant spread was obtained both in the East_West and North-South directions and is presented under the following headings:

East-West

The data on the plant spread in East-West direction of different treatment of growth regulators are presented in table 2. There was a significant difference in the plant spread among the treatment at 180 days after transplanting. Plant spread was recorded in the range of 46.07 cm to 51.80 cm. The treatment GA3 at 200 ppm (51.80 cm) recorded maximum plant spread. The least plant spread (46.07 cm) was observed in control (T1).

North-South

The data on the plant spread in North-South direction at different stages of crop growth for different treatment of growth regulators are presented in Table 2. The difference in the plant spread among the treatment at 180 days after transplanting was also significant. Plant spread was recorded in the range of 37.07 cm to 44.61 cm. The treatment GA3 at 150 ppm (T7) recorded maximum plant spread (44.61 cm) and the least plant spread (37.07 cm) was observed in control (T1).

Table 2: Influence of different plant growth regulators on flower per spike, Days taken to first harvest,flower duration, flowers per spike, 100 flower wt (g),flower yield per plant(g),flower yield per plot(g).

Treatment details	Number of branches/plants at different DAT						Plant spread at 180 DAT	
	30	60	90	120	150	180	N-S	E-W
T1 - CONTROL	2.56	4.35	7.93	11.85	13.96	14.60	37.07	46.07
T2 - NAA @ 50 ppm	3.61	5.63	10.29	12.49	16.61	17.02	43.18	49.15
T3 - NAA @ 100 ppm	3.39	5.53	9.28	12.41	15.38	16.17	42.41	48.74
T4 - NAA @ 150 ppm	3.17	5.43	8.27	12.33	14.15	14.86	41.64	48.33
T5 - GA3 @ 50 ppm	3.36	5.60	9.04	13.92	15.58	16.23	42.59	49.50
T6 - GA3 @ 100 ppm	3.49	5.86	9.71	14.02	15.97	16.62	43.60	50.65
T7 - GA3 @ 150 ppm	3.63	6.13	10.39	14.12	16.37	17.48	44.61	51.80
T8 - CCC @ 500 ppm	3.08	5.26	8.78	13.61	15.34	15.92	39.49	46.40
T9 - CCC @ 750 ppm	3.23	5.54	9.48	13.77	15.74	16.36	41.00	48.05
T10 - CCC @ 1000 ppm	3.39	5.83	10.19	13.93	15.61	16.17	40.34	47.62
T11 - MH @ 100 ppm	3.00	5.33	8.75	13.57	15.24	15.94	39.69	46.60
T12 - MH @ 200 ppm	3.16	5.58	9.43	13.65	15.75	16.40	41.40	48.45
T13 - MH @ 300 ppm	3.33	5.84	10.12	13.73	14.57	15.31	39.79	49.44
S. Em (+)	0.12	0.14	0.25	0.48	0.23	0.13	0.51	0.95
CD at 5 %	0.35	0.41	0.73	1.46	0.68	0.39	1.56	2.73

DAT: Days after transplanting NS: Non-significant

Flowering and yield parameters

The data on flowering parameters like days taken to flower spike initiation, days taken to first harvest and duration of flowering after bending are furnished in Table 3.

Days taken to flower spike initiation

The treatments differed significantly for the days required to first flower spike initiation. The treatment GA3 at 50 ppm (T7) was early to show its visible flower spike in 32.61 days after transplanting. The treatment control (T1) (45.43 DAT) was late to initiate a flower spike.

Days taken to first harvest

The treatments differ significantly for days taken to first harvest. The treatment GA3 at 50 ppm (T1) was early to harvest in 51.04 days after transplanting and control (T1) shown late to harvest the flowers (61.19 DAT).

Duration of flowering

Results revealed that the significant variation among the treatments of different growth regulator treatments for the duration of flowering. The flower duration period was maximum in the treatment GA3 at 150 ppm (125.27 days) and it was minimum in control (110.62 days). In general, the plants treated with GA were early to produce the first flower than control plants. This might be due to the effect of gibberellins, as gibberellins influences florigen which is required for the formation of flowers which leads to early harvesting of flowers and enhance flowering duration. These results are in accordance with Binisundar *et al.* (2008) in crossandra, Girish *et al*. (2012) [8] in daisy and Doddagoudar *et al*. (2004) [5] in China aster.

The data pertaining yield and other parameters like the number of flowers per spike, number of spikes per plant, 100 flower weight, flower yield per plant, flower yield per plot and flower yield per hectare were recorded. The treatment GA3 at 150 ppm (38.88) had the maximum number of spikes per plant. The least number of spikes per plant (34.66) was observed in MH@100 ppm (T11).

Results revealed a significant variation among the use of different growth regulators for the number of flowers per spike. Production of flower per spike was maximum (50.52) in T7 (GA3 at 150 ppm) which was found superior over all the treatment while, flowers per spike production were minimum (48.00) in the MH@100 ppm. For the parameter, 100 flower weight varied significantly among the different growth regulators treatment. The maximum (7.01 g) 100 flower weight was observed in T7 (GA3 at 150 ppm). The lowest 100 flower weight (6.07 g) was recorded in the T10 (CCC @ 1000 ppm).

Treatments differ significantly for flower yield per plant. The treatment T7 (GA3 at 150 ppm) recorded maximum (79.52 g) flower yield per plant and it was minimum (69.44 g) T1 (control). In this study, GA3 at 150 ppm produced profuse flowers per plant. This might be due to the production of optimum plant stature, increased number of branches, leaf area and plant spread, which in turn enabled them to produce an increased amount of photosynthesis, ultimately resulting in accumulation of maximum dry matter, increased flower duration, yield, and quality. Similar findings were also reported by Kulkarni (2004) [8] in chrysanthemum. Talukdar and Paswan (1996) in chrysanthemum by using GA. The increase in yield and yield parameters with GA3 at 150 ppm spraying was due to enhanced reproductive efficiency and photosynthesis in restructured plant type produced more number of flowers per plant and ultimately increased the flower yield per plot. This can be attributed to the translocation of the source to sink. Similar results were reported by Binisundar *et al*. (2008) in crossandra, Shetty (1995) [15] and Doddagoudar *et al* (2004) [5] in China aster and Prabhatkumar *et al*. (2003) in China aster.

Table 2: Influence of different plant growth regulators on flower per spike, Days taken to first harvest, flower duration, flowers per spike, 100 flower wt (g), flower yield per plant(g),flower yield per plot(g).

Treatment details	Flower spike initiation	Days taken to first harvest	Flower duration	Flowers per spike	100 flower wt (g)	Flower yield per plant (g)	Flower yield per plot (g)
T1 - CONTROL	45.43	61.19	110.62	47.41	6.80	69.44	1043.54
T2 - NAA @ 50 ppm	45.00	59.53	123.78	48.19	6.84	71.36	1065.08
T3 - NAA @ 100 ppm	44.77	59.59	119.83	47.99	6.85	71.71	1073.90
T4 - NAA @ 150 ppm	44.54	59.65	115.88	47.79	6.86	72.06	1082.72
T5 - GA3 @ 50 ppm	35.85	51.04	117.05	48.25	6.17	75.40	1130.68
T6 - GA3 @ 100 ppm	34.23	52.35	121.16	49.38	6.97	77.46	1161.47
T7 - GA3 @ 150 ppm	32.61	53.67	125.27	50.52	7.01	79.52	1192.26
T8 - CCC @ 500 ppm	33.41	57.64	114.45	45.45	6.63	72.80	1127.58
T9 - CCC @ 750 ppm	34.93	59.15	118.86	46.78	6.85	75.16	1158.97
T10 - CCC @ 1000 ppm	36.45	60.67	123.27	48.12	6.07	77.52	1190.36
T11 - MH @ 100 ppm	33.41	58.34	114.15	44.65	6.34	72.50	1127.18
T12 - MH @ 200 ppm	34.93	59.55	118.36	46.08	6.25	74.66	1157.77
T13 - MH @ 300 ppm	36.45	60.77	122.57	47.52	6.17	76.82	1188.36
S. Em (+)	1.57	0.08	1.83	0.42	0.01	1.41	2.85
CD at 5 %	4.63	0.29	5.63	1.43	0.04	4.61	8.01

DAT: Days after transplanting NS: Non-significant

Conclusion

From the results of investigation it was concluded that the plants sprayed with GA3 at 150 ppm improves the growth, development and flower yield of crossandra cv.Arka Ambara and this growth regulator was evolved as suitable growth regulators in order to get more yield with good quality flowers.

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