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MODULATION OF GROWTH AND FLOWER YIELD IN CHINA ASTER (*Callistephus chinensis* L. NEES) CULTIVARS THROUGH PLANT GROWTH REGULATORS

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ABSTRACT

Callistephus chinensis (L.) Nees, also referred to as Annual Aster or China aster, is a flowering plant belongs to the plant family Asteraceae and is indigenous to Northern China. The present investigation was done to assess the effect of different plant growth regulator on growth and development of China aster. The experiment was laid out by following Factorial Randomized Block Design, with two factors *viz*.; cultivars and plant growth regulators. The experimental study revealed that between the two cultivars, cv. Arka Shashank (V_1) showed early flowering (79.52 days) compared to cv. Arka Kamini (V_2), but the longer duration of flowering (64.86 days) was observed with the cv. Arka Kamini (V_2). Among the plant growth regulators, the treatment T_1 (GA_3 @ 300 ppm) gave the maximum plant height, maximum plant spread (E-W and N-S), more number of leaves per plant, more number of branches per plant, maximum flower duration, maximum flower diameter, highest number of flowers per plant, highest number of flowers per plot, maximum stalk length, maximum weight of 10 fresh flowers, maximum number of seeds and seed weight whereas minimum days for 1st flower bud initiation, days for 1st flower bud opening and days for 1st flower full blooming observed in treatment T_{11} (NAA @ 200 ppm + BR @ 1 ppm). The best quality flowers and seeds were found when China aster plants treated with GA_3 @ 300 ppm. Hence, it can be concluded that among the different plant growth regulators and cultivars of China aster GA_3 @ 300 ppm and cv. Arka Shashank may be recommended for qualitative and quantitative production of China aster in the Terai region of West Bengal.

Key words : Arka Shashank, GA_3, China Aster, NAA, Plant growth regulators.

Introduction

China Aster [*Callistephus chinensis* (L.) Nees], a member of the family Asteraceae, is native to China and is widely cultivated across many parts of the world as an important annual ornamental crop (Navalinskien *et al*., 2005). Among annual flowering plants, it holds a prominent position, ranking next to Chrysanthemum and Marigold in terms of popularity and cultivation (Sarkar, 2023). Cassini described the China aster as *Callistephus hortensis*. It was first named by Linnaeus as Aster chinensis and Nees subsequently changed name to *Callistephus chinensis* (Parameshwar, 2017). China aster is a semi hardy, self-pollinated, winter annual crop with chromosomal number 2n=18. The plant produces flowers that range in colour from white to creamy yellow, pink, blue, red and purpleand has an upright branching habit. China aster might easily be adapted to various agro-climatic conditions, allowing year-round production (Munikrishnappa and Chandrashekar, 2014).

Plant growth and yield are primarily governed by two major factors, namely genetic makeup and crop management practices. In recent years, considerable

emphasis has been placed on the use of plant growth regulators as an additional important factor influencing plant growth, yield and flower quality. These substances alter physiological and biochemical processes within the plant system, thereby affecting overall growth and development (Aklade *et al.*, 2009). Synthetic growth-regulating chemicals have gained significant importance in commercial floriculture due to their effectiveness in manipulating vegetative growth, flowering behaviour and quality attributes of several ornamental and flower crops (Vijayakumar *et al.*, 2017).

Plant growth regulators are widely used for enhancing plant productivity through the regulation of growth, development and stress responses (Shukla and Farooqi, 1990). Synthetic plant growth regulators, including auxins, cytokinins and gibberellins are applied to plants to influence various physiological processes and the biosynthesis of important plant constituents (Kewalanand and Pandey, 1998). Among these, Gibberellic acid (GA_3) and Naphthalene Acetic Acid (NAA) play significant roles in improving vegetative growth by stimulating cell elongation and division through enhanced deoxyribonucleic acid (DNA) synthesis within cells (Murugan *et al.*, 2020). Homobrassinolide is also known to promote cell expansion and elongation (Clouse and Sasse, 1998) and its effect becomes more pronounced when combined with auxins (Nemhauser *et al.*, 2004). In addition, it facilitates pollen elongation and pollen tube formation, thereby supporting reproductive development (Hewitt *et al.*, 1985). Plant growth regulators act as chemical messengers for intercellular communication and hence play an essential role in modifying plant morphology and physiology. Various methods for using growth regulators are in usage. Foliar application is the most popular since it is simple, practical, inexpensive and cost-effective. It has had a considerable impact on plant growth, flowering, seed set and seed production.In recent years, growth regulators have played a significant role in overcoming the factors limiting yield and quality in order to maximise the profit from seed production. It was discovered that foliar application of plant growth regulators increased the number of blooms per plant as well as seed yield per plant (Kumar *et al.*, 2015).

Considering the significance of plant growth regulators in enhancing the productivity, yield and quality of seed and flower in China aster, the present investigation was done to study the effect of plant growth regulators on growth and yield of China aster (*Callistephus chinensis* L. Nees) cultivars in Terai region of West Bengal.

Materials and Methods

The experiment was conducted at the Instructional Farm, Department of FMAP, Faculty of Horticulture UBKV, Pundibari, Cooch Behar, West Bengal, India-736165. The experiment was laid out by following factorial randomized block design, consists of two factors in which first factor was cultivars (V_1- Arka Shashank and V_2- Arka Kamini) and second factor was plant growth regulators *i.e.*, T_1- GA_3 @ 300 ppm, T_2- NAA @ 200 ppm, T_3- BR (Homobrassinolide) @ 0.25 ppm, T_4- BR @ 0.50 ppm, T_5- BR @ 0.75 ppm, T_6- BR @ 1 ppm, T_7- BR @ 1.25 ppm, T_8- NAA @ 200 ppm + BR @ 0.25 ppm, T_9- NAA @ 200 ppm + BR @ 0.50 ppm, T_{10}- NAA @ 200 ppm + BR @ 0.75 ppm, T_{11}- NAA @ 200 ppm + BR @ 1 ppm, T_{12}- NAA @ 200 ppm + BR @ 1.25 ppm and T_{13}- Control (distilled water), replicated thrice. The plot size was 120 cm × 120 cm. Total 16 numbers of plats were planted per plot with a spacing of 30 cm × 30 cm.

Preparation and Application of Plant Growth regulators

Gibberellic Acid (GA_3) : The stock solution of Gibberellic acid (GA_3) was prepared by dissolving 300 mg of GA*f* in a small quantity of ethanol (C_2H_5OH). Distilled water was then added to make up the final volume to 1000 ml, resulting in a 300 ppm stock solution (Chettri *et al.*, 2025).

Naphthalene Acetic Acid (NAA) : For the preparation of the NAA stock solution, 200 mg of Naphthalene Acetic Acid was dissolved in a small amount of acetone [$(CH_3)_2CO$]. The volume was subsequently made up to 1000 ml with distilled water to obtain a 200 ppm stock solution.

Homobrassinolide (BR) : A commercial formulation of Homobrassinolide, marketed under the name 'Double' (Homobrassinolide 0.04% w/w), was used in the experiment. The formulation contained 40 mg of homobrassinolide per 100 ml of product. To prepare a 1 ppm solution, 0.5 ml of the formulation was mixed with 200 ml of distilled water. Similarly, for preparing 1.25 ppm, 0.75 ppm, 0.5 ppm and 0.25 ppm solutions, 0.625 ml, 0.375 ml, 0.25 ml and 0.125 ml of the formulation, respectively, were diluted in 200 ml of distilled water.

Application of Plant Growth Regulators : The prepared plant growth regulator solutions were applied as foliar sprays during the early morning hours using a 1-litre hand sprayer. Spraying was carried out uniformly to ensure complete wetting of the leaf surfaces. The sprayer was thoroughly cleaned after each application to prevent

contamination among treatments. All growth regulator treatments were imposed twice, at 45 and 60 days after transplanting, according to the experimental schedule.

Results and Discussion

Vegetative parameters

Plant growth regulators significantly enhanced the vegetative parameters of two China aster varieties. Maximum plant height (96.45cm), plant spread North-South (53.67cm) and East-West (51.11cm), number of branches (21.22), number of leaves per plant (339.57) were recorded in cv. Arka Shashank (V_1) with the application of GA_3 @ 300 ppm (T_1), whereas the minimum was observed in cv. Arka Kamini (V_2) with treatment T_{13} (Control) for all the vegetative parameters (Table 1). The maximum percent increase of plant height (17.24%) was observed with the treatment T_1 (GA_3 @ 300 ppm) followed by T_{10} (NAA @ 200 ppm + BR @ 0.75 ppm) of 14.85% with respect to control (Fig. 1). This might be due to the fact that, GA_3 effects protein biosynthesis translocation and transcription mechanisms as well as stimulation of cell division and elongation while enhancing cell wall plasticity and the formation of energy-rich phosphates, resulting in an increase in plant height with more number of productive branches and thus increased the spread of plant. Enhanced vegetative traits may be due to improved metabolic and photosynthetic activity caused by GA_3. GA_3 promotes plant growth by increasing internodal length, which may be due to greater cell division and cell enlargement as well as increased cell plasticity, protein synthesis stimulation and higher apical dominance (Murugan *et al.*, 2020). Similar findings were recorded in earlier studies by Bhandari *et al.* (2022) in China aster, Kumar *et al.* (2018) in China aster, Mujadidi *et al.* (2019) in African marigold.

Flowering parameters

Flowering parameters significantly influenced by different treatments under study. Minimum days taken for first flower bud initiation (72.00 days) and first flower bud opening (10.33 days) were observed in cv. Arka Shashank (V_1) with the application of NAA @ 200 ppm + BR @ 1 ppm spray (T_{11}) whereas the maximum was recorded in cv. Arka Kamini (V_2) with the application of distilled water (Control-T_{13}) (Table 2). Minimum days of first flower full blooming (18.67 days) were observed in cv. Arka Kamini (V_2) with the application of NAA @ 200 ppm + BR @ 1 ppm spray (T_{11}) whereas the maximum was recorded in cv. Arka Kamini (V_2) with the application of distilled water (Control-T_{13}). Maximum days taken for first flower wilting (18.00 days) were observed in cv. Arka Kamini (V_2) with application of

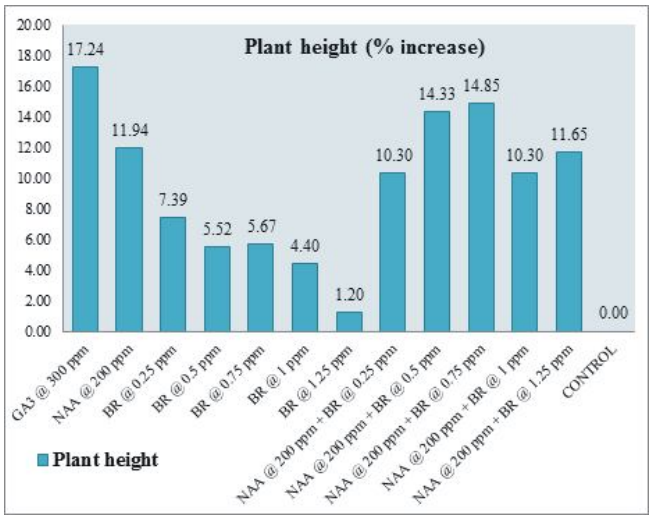


Fig. 1 : Effect of plant growth regulators on percent increase of plant height as compared to Control.

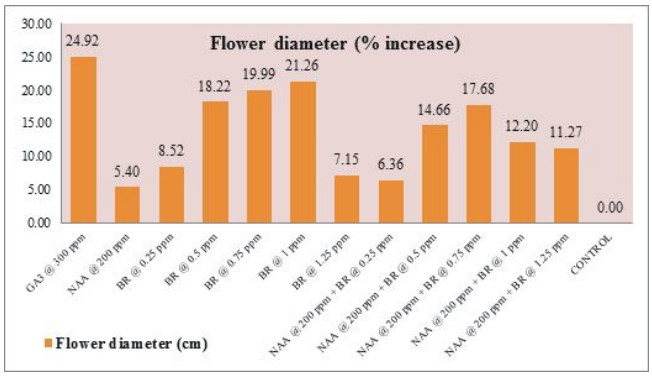


Fig. 2 : Effect of plant growth regulators on percent increase of flower diameter as compared to control.

NAA @ 200 ppm + BR @ 1.25 ppm spray (T_{12}), whereas minimum days of first flower wilting (11.33 days) in cv. Arka Shashank (V_1) with Control (T_{13}) (Table 2). Maximum duration of flowering (69.55 days), maximum flower diameter (6.65cm) were observed in Arka Kamini treated with GA_3 @ 300 ppm (T_1V_2) followed by T_2 (67.78 days) whereas minimum duration of flowering (55.00 days) was recorded in Arka Shashank treated with distilled water ($T_{13}V_1$) and minimum flower diameter (4.76 cm) was observed in Arka Shashank (V_1) treated with distilled water (T_{13}). The percent increase of flower diameter as compared with the control (T_{13}) was calculated the highest percent increase (24.92%) was found with the treatment GA_3 @ 300 ppm (T_1) (Fig. 2). The application of GA_3 @ 300 ppm (T_1) recorded maximum flower stalk length (34.78 cm) in cv. Arka Shashank (V_1). Application of distilled water (Control) (T_{13}) recorded minimum flower stalk length (18.56 cm) in cv. Arka Kamini (V_2) (Table 3). The highest percent increase (52.69 %) in flower stalk length was found with the treatment GA_3 @ 300 ppm (T_1) as compared to the control (Fig. 3). Maximum weight of 10 fresh flowers

Table 1 : Effect of cultivars and plant growth regulators on plant height, plant spread, number of branches per plant and number of leaves per plant of China aster.

Treatment details	Plant height	Plant Spread (N-S)	Plant Spread (E-W)	No. of Branches/plant	No. of leaves/ plant
First Factor (V)					
V_1	90.40	46.77	46.01	16.47	237.86
V_2	71.63	43.49	44.22	14.09	185.60
S. Em±	0.10	0.12	0.11	0.07	1.06
C.D. at 5%	0.28	0.35	0.32	0.20	3.01
Second Factor (T)					
T_1	87.28	50.61	49.50	19.33	283.17
T_2	83.33	46.89	46.28	17.39	229.50
T_3	79.95	44.33	44.78	14.89	186.49
T_4	78.56	43.61	44.50	13.56	170.95
T_5	78.67	43.11	44.06	13.17	215.52
T_6	77.72	42.67	43.17	12.17	176.24
T_7	75.33	41.78	41.67	11.67	188.43
T_8	82.11	44.89	45.39	15.72	209.05
T_9	85.11	48.72	48.17	18.33	273.09
T_{10}	85.50	48.00	47.50	17.83	245.03
T_{11}	82.11	45.78	45.67	17.00	238.01
T_{12}	83.11	45.50	45.22	16.78	207.07
T_{13}	74.44	40.78	40.61	10.83	129.99
S. Em±	0.25	0.31	0.29	0.18	2.70
C.D. at 5%	0.72	0.88	0.82	0.51	7.68
Treatment Combinations (V x T)					
$V_1 \times T_1$	96.45	53.67	51.11	21.22	339.57
$V_1 \times T_2$	93.11	49.00	47.44	19.11	286.65
$V_1 \times T_3$	88.56	45.67	45.67	15.67	203.67
$V_1 \times T_4$	87.33	44.67	45.44	14.56	203.79
$V_1 \times T_5$	87.56	44.11	45.11	12.78	268.36
$V_1 \times T_6$	87.11	43.66	43.67	12.56	175.79
$V_1 \times T_7$	85.56	42.78	41.67	12.55	225.98
$V_1 \times T_8$	92.89	46.44	46.78	17.00	187.00
$V_1 \times T_9$	93.56	51.00	49.44	20.22	283.08
$V_1 \times T_{10}$	93.56	50.89	49.11	19.55	312.85
$V_1 \times T_{11}$	92.11	47.11	46.67	18.67	261.33
$V_1 \times T_{12}$	93.34	46.78	46.00	18.56	204.12
$V_1 \times T_{13}$	84.11	42.22	40.00	11.67	140.00
$V_2 \times T_1$	78.11	47.56	47.89	17.44	226.76
$V_2 \times T_2$	73.56	44.78	45.11	15.67	172.35
$V_2 \times T_3$	71.33	43.00	43.89	14.11	169.32
$V_2 \times T_4$	69.78	42.56	43.56	12.55	138.10
$V_2 \times T_5$	69.78	42.11	43.00	13.56	162.68
$V_2 \times T_6$	68.33	41.67	42.67	11.78	176.68
$V_2 \times T_7$	65.11	40.78	41.67	10.78	150.87
$V_2 \times T_8$	71.33	43.33	44.00	14.44	231.09
$V_2 \times T_9$	76.67	46.45	46.89	16.44	263.09
$V_2 \times T_{10}$	77.44	45.11	45.89	16.11	177.21
$V_2 \times T_{11}$	72.11	44.45	44.67	15.33	214.68
$V_2 \times T_{12}$	72.89	44.22	44.44	15.00	210.02
$V_2 \times T_{13}$	64.78	39.33	41.22	10.00	119.99
S. Em±	0.36	0.44	0.41	0.26	3.81
C.D. at 5%	1.01	1.25	1.15	0.73	10.86

Table 2 : Effect of cultivars and plant growth regulators on days taken for first flower bud initiation, bud opening, full blooming, wilting, duration of flowering and flower diameter of China aster.

Treatment details	Days for first flower bud initiation (FFI)	Days for first flower bud opening (FFB)	Days for first flower full blooming (FFF)	Days for first flower wilting (FFW)	Duration of flowering (days)	Flower diameter (cm)
First Factor (V)						
V_1	79.52	12.36	21.73	13.59	58.84	5.23
V_2	87.79	15.57	22.16	15.28	64.86	5.98
S. Em±	0.07	0.06	0.07	0.05	0.09	0.01
C.D. at 5%	0.19	0.16	0.21	0.16	0.24	0.03
Second Factor (T)						
T_1	85.17	14.50	22.39	13.33	63.44	6.21
T_2	86.67	14.89	22.67	12.83	62.11	5.24
T_3	82.67	13.84	21.94	14.67	62.89	5.39
T_4	81.55	13.89	21.61	14.39	62.95	5.87
T_5	79.33	12.89	21.00	14.78	63.44	5.96
T_6	78.22	12.39	20.67	14.89	63.22	6.02
T_7	91.89	15.89	23.83	15.72	60.67	5.32
T_8	83.78	14.28	22.11	14.06	61.33	5.28
T_9	80.50	13.17	21.39	13.83	62.28	5.70
T_{10}	77.50	12.28	20.44	15.11	62.67	5.85
T_{11}	76.78	11.50	19.39	15.33	62.67	5.57
T_{12}	90.39	15.28	23.11	16.67	58.89	5.53
T_{13}	93.06	16.72	24.72	12.06	57.50	4.97
S. Em±	0.17	0.14	0.18	0.14	0.22	0.03
C.D. at 5%	0.49	0.41	0.52	0.40	0.62	0.07
Treatment Combinations (V x T)						
$V_1 \times T_1$	81.89	12.56	22.11	12.45	57.33	5.76
$V_1 \times T_2$	82.67	12.78	22.44	12.11	56.44	4.95
$V_1 \times T_3$	78.33	11.89	21.44	14.00	59.22	5.07
$V_1 \times T_4$	77.32	12.44	21.44	13.67	59.78	5.41
$V_1 \times T_5$	74.33	11.67	21.00	14.11	60.89	5.44
$V_1 \times T_6$	73.56	11.33	20.67	14.11	61.22	5.49
$V_1 \times T_7$	88.22	14.22	23.00	14.56	56.00	5.02
$V_1 \times T_8$	79.89	12.11	21.78	13.33	57.78	5.00
$V_1 \times T_9$	75.67	12.00	21.22	13.00	60.56	5.28
$V_1 \times T_{10}$	73.00	11.11	20.44	14.22	61.89	5.37
$V_1 \times T_{11}$	72.00	10.33	20.11	14.44	62.44	5.23
$V_1 \times T_{12}$	87.11	13.22	22.67	15.33	56.33	5.21
$V_1 \times T_{13}$	89.78	15.00	24.11	11.33	55.00	4.76
$V_2 \times T_1$	88.44	16.45	22.67	14.22	69.55	6.65
$V_2 \times T_2$	90.67	17.00	22.89	13.56	67.78	5.52
$V_2 \times T_3$	87.00	15.78	22.44	15.33	66.56	5.71
$V_2 \times T_4$	85.78	15.33	21.78	15.11	66.11	6.33
$V_2 \times T_5$	84.33	14.11	21.00	15.44	66.00	6.48
$V_2 \times T_6$	82.89	13.45	20.67	15.67	65.22	6.56
$V_2 \times T_7$	95.56	17.56	24.67	16.89	65.34	5.62
$V_2 \times T_8$	87.67	16.44	22.44	14.78	64.89	5.57
$V_2 \times T_9$	85.33	14.33	21.56	14.67	64.00	6.11
$V_2 \times T_{10}$	82.00	13.45	20.44	16.00	63.44	6.32
$V_2 \times T_{11}$	81.56	12.67	18.67	16.22	62.89	5.91
$V_2 \times T_{12}$	93.67	17.33	23.56	18.00	61.44	5.84
$V_2 \times T_{13}$	96.34	18.45	25.33	12.78	60.00	5.18
S. Em±	0.24	0.20	0.26	0.20	0.31	0.04
C.D. at 5%	0.69	0.57	0.74	0.56	0.87	0.11

Table 3 : Effect of cultivars and plant growth regulators on flower stalk, weight of 10 fresh flowers, total no. of flowers per plant and plot, vase life as cut flower of China aster.

Treatment details	Flower stalk length (cm)	Weight of 10 fresh flowers (gm)	Total no. of flowers per plant	Total no. of flowers per plot	Vase life (days)
First Factor (V)					
V_1	30.65	19.14	50.64	810.26	10.11
V_2	24.59	21.49	47.13	754.06	9.11
S. Em±	0.06	0.07	0.11	1.77	0.04
C.D. at 5%	0.18	0.20	0.32	5.03	0.11
Second Factor (T)					
T_1	33.17	25.38	61.28	980.44	12.33
T_2	22.67	15.78	37.22	595.55	10.06
T_3	26.56	18.78	44.61	713.79	7.67
T_4	29.94	22.65	55.39	886.22	7.94
T_5	30.89	23.65	56.89	910.21	8.17
T_6	32.17	24.52	57.89	926.25	10.44
T_7	24.83	17.65	43.33	693.33	11.00
T_8	23.72	16.27	40.39	646.24	8.33
T_9	28.56	21.78	52.50	840.00	8.94
T_{10}	29.39	22.60	54.06	864.89	9.39
T_{11}	27.83	20.93	50.72	811.55	11.89
T_{12}	27.61	19.72	47.11	753.78	11.67
T_{13}	21.72	14.37	34.11	545.79	7.17
S. Em±	0.16	0.18	0.28	4.50	0.09
C.D. at 5%	0.45	0.50	0.80	12.83	0.27
Treatment Combinations (V x T)					
$V_1 \times T_1$	34.78	24.03	62.33	997.33	13.22
$V_1 \times T_2$	26.22	15.73	39.89	638.24	10.22
$V_1 \times T_3$	30.44	17.27	46.67	746.67	8.22
$V_1 \times T_4$	32.44	20.87	57.44	919.09	8.44
$V_1 \times T_5$	32.89	21.77	58.67	938.67	8.78
$V_1 \times T_6$	33.78	23.23	59.22	947.57	10.67
$V_1 \times T_7$	29.11	16.60	45.33	725.33	11.44
$V_1 \times T_8$	27.67	16.20	41.78	668.43	9.00
$V_1 \times T_9$	31.78	20.20	54.22	867.57	9.33
$V_1 \times T_{10}$	32.11	21.07	55.44	887.09	9.56
$V_1 \times T_{11}$	31.33	19.43	52.78	844.43	12.44
$V_1 \times T_{12}$	31.00	18.23	48.33	773.32	12.22
$V_1 \times T_{13}$	24.89	14.17	36.22	579.57	7.89
$V_2 \times T_1$	31.56	26.73	60.22	963.54	11.44
$V_2 \times T_2$	19.11	15.83	34.55	552.85	9.89
$V_2 \times T_3$	22.67	20.30	42.56	680.91	7.11
$V_2 \times T_4$	27.44	24.43	53.33	853.35	7.44
$V_2 \times T_5$	28.89	25.53	55.11	881.76	7.56
$V_2 \times T_6$	30.56	25.80	56.56	904.92	10.22
$V_2 \times T_7$	20.56	18.70	41.33	661.33	10.56
$V_2 \times T_8$	19.78	16.33	39.00	624.05	7.67
$V_2 \times T_9$	25.33	23.37	50.78	812.43	8.56
$V_2 \times T_{10}$	26.67	24.13	52.67	842.68	9.22
$V_2 \times T_{11}$	24.33	22.43	48.67	778.67	11.33
$V_2 \times T_{12}$	24.22	21.20	45.89	734.24	11.11
$V_2 \times T_{13}$	18.56	14.57	32.00	512.00	6.44
S. Em±	0.22	0.25	0.40	6.37	0.13
C.D. at 5%	0.63	0.71	1.14	18.14	0.38

(26.73 g) was noted in Arka Kamini (V_2) treated with GA_3 @ 300 ppm (T_1) followed by V_2T_6 (25.80 g) whereas application of distilled water (T_{13}) recorded minimum weight of 10 fresh flowers (14.17 g) in cv. Arka Shashank (V_1) (Table 3). The percent increase of weight of 10 fresh flowers was calculated as compared with the control (T_{13}). The highest percent increase (76.68 %) was found with the treatment GA_3 @ 300 ppm (Fig. 4). Maximum total numbers of flowers per plant (62.33) and per plot (997.33) were observed in cv. Arka Shashank (V_1) with the application of GA_3 @ 300 ppm (T_1), whereas V_2T_{13} recorded the minimum total number of flowers per plant (32.00) and minimum total number of flowers per plot (512.00). GA_3 @ 300 ppm (T_1) showed the highest percent increase (79.64 %) in total number of flowers per plant as compared to the control (Fig. 5). Maximum vase life was recorded in Arka Shashank treated with GA_3 @ 300 ppm (V_1T_1) whereas minimum (6.44 days) was recorded in T_{13} (Table 3). Earliness of flowering may be due to inhibition of physiological process like retarding the abscission and ethylene biosynthesis within the plant (Ali *et al.*, 2008, Ali *et al.*, 2012 and Nolan *et al.*, 2020). Similar findings of early flowering using BR were recorded in tuberose by Laksmi *et al.* (2021). NAA and BR both enhances the cell division and cell elongation which results large number of laterals at early stage which promotes the early bud initiation (Nemhauser *et al.*, 2004). BR has the ability of pollen elongation for pollen tube formation (Hewitt *et al.*, 1985). This might be the reason of early full blooming. Gibberellin accumulates more carbohydrates in plant body which leads to lengthening of flowering span. It is a component of florigen, which is required for flower development. Increase in length of petals and pedicels might be due to cell elongation in the flower. Similar findings were observed by Bhandari *et al.* (2022) and Sindhuja *et al.* (2018) in China aster as well as in African marigold by Swaroop *et al.* (2007).The enhancement in number of flowers per plant with gibberellin might be due to the production of large number of laterals at early stage of growth which had sufficient time to accumulate carbohydrate for proper flower bud differentiation. Similar findings were observed by Bhandari *et al.* (2022) and Sindhuja *et al.* (2018) in China aster as well as in African marigold by Swaroop *et al.* (2007).

Seed parameters

GA_3 @ 300 ppm significantly enhanced the seed parameters. Maximum weight of 1000 seeds (2.35 g), seed length (3.94 mm), maximum total number of seeds per flower (62.33), maximum weight of seeds per square meter (101.37 g) were observed in Arka Shashank (V_1)

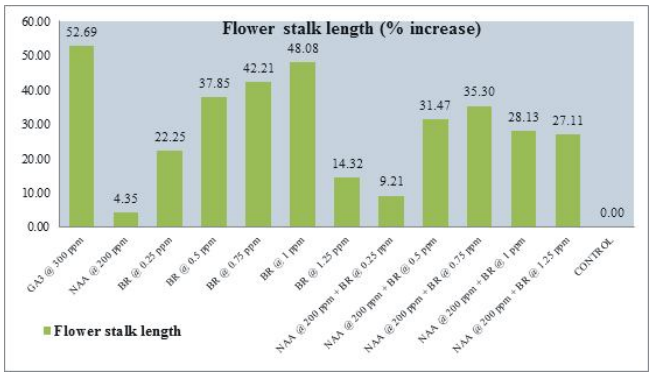


Fig. 3 : Effect of plant growth regulators on percent increase of flower stalk length as compared to Control.

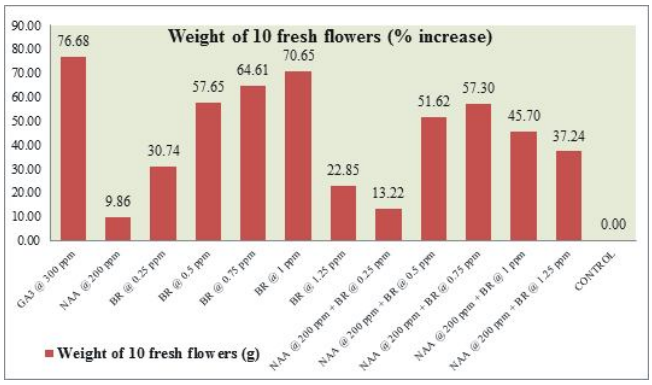


Fig. 4 : Effect of plant growth regulators on percent increase of weight of 10 fresh flowers as compared to Control.

with the application of GA_3 @ 300 ppm (T_1), whereas the minimum weight of 1000 seeds (1.06 g) observed in V_1T_{13}, minimum seed length (2.94 mm), was recorded in V_2T_{13}, and minimum weight of seeds per square meter (18.49 g) were recorded in V_1T_{13} (Table 4). The highest percent increase in weight of seeds per square meter as compared to the control was observed with the application of GA_3 @ 300 ppm (T_1) *i.e.*; 340.91 % (Fig 6). GA_3 @ 300 ppm (T_1) recorded maximum viability percentage (80.00%) in Arka Kamini (V_2). In case of moisture content (%) the application of NAA @ 200 ppm (T_2) recorded maximum moisture content (8.55 %) in cv. Arka Kamini (V_2) whereas application of BR @ 0.50 ppm (T_4) recorded minimum moisture content (4.38 %) in cv. Arka Shashank (V_1) (Table 4). The plants treated with GA_3 @ 300 ppm gave the maximum seed weight, total number of seeds per plant, seed length and breadth. Similar results regarding seed weight and number of seeds per plant were observed by Doddagoudar *et al.* (2002) in China aster, Patil *et al.* (2014) in African marigold. GA_3 enhances photosynthesis and other metabolic activities and thus it might have produced better quality flowers with bolder seeds. This might be the reason of higher test weight of seeds, seed length and breadth with the treatment of gibberellic acid. In case of seed viability percentage and moisture content of the seeds, it was

Table 4 : Effect of cultivars and plant growth regulators on test weight, seed length, seed breadth, total number of seeds per flower and weight of seeds per meter square of China aster.

Treatment details	Weight of 1000 seeds (g)	Seed length (mm)	Seed breadth (mm)	Total no. of seeds per flower	Weight of seeds per square meter (g)
First Factor (V)					
V_1	1.98	3.45	1.02	43.46	52.73
V_2	1.59	3.23	1.09	56.13	48.36
S. Em±	0.03	0.02	0.01	0.27	0.26
C.D. at 5%	0.08	0.06	0.02	0.78	0.75
Second Factor (T)					
T_1	2.01	3.69	1.24	65.33	88.89
T_2	1.64	3.43	1.09	39.17	26.22
T_3	1.77	3.22	1.01	46.17	39.78
T_4	1.88	3.29	1.03	55.17	62.70
T_5	1.93	3.33	1.04	56.83	67.95
T_6	1.96	3.38	1.07	60.67	75.12
T_7	1.75	3.16	0.98	42.67	35.29
T_8	1.67	3.11	0.95	42.00	31.03
T_9	1.84	3.49	1.14	52.17	55.05
T_{10}	1.85	3.56	1.17	54.00	59.18
T_{11}	1.82	3.46	1.13	50.00	50.24
T_{12}	1.81	3.24	0.99	49.00	45.46
T_{13}	1.29	3.02	0.89	34.17	20.16
S. Em±	0.07	0.05	0.02	0.70	0.67
C.D. at 5%	0.20	0.14	0.06	1.98	1.90
Treatment Combinations (V x T)					
$V_1 \times T_1$	2.35	3.94	1.19	62.33	101.37
$V_1 \times T_2$	1.76	3.55	1.03	34.00	26.53
$V_1 \times T_3$	1.97	3.31	0.98	39.33	40.10
$V_1 \times T_4$	2.13	3.40	0.99	48.67	66.13
$V_1 \times T_5$	2.23	3.46	1.00	49.67	72.02
$V_1 \times T_6$	2.27	3.46	1.01	54.00	80.59
$V_1 \times T_7$	1.94	3.22	0.97	36.00	35.05
$V_1 \times T_8$	1.78	3.15	0.95	35.00	29.04
$V_1 \times T_9$	2.09	3.61	1.11	45.33	56.96
$V_1 \times T_{10}$	2.09	3.70	1.13	47.33	61.13
$V_1 \times T_{11}$	2.05	3.59	1.08	43.33	51.99
$V_1 \times T_{12}$	2.03	3.32	0.98	42.33	46.11
$V_1 \times T_{13}$	1.06	3.09	0.86	27.67	18.49
$V_2 \times T_1$	1.67	3.44	1.28	68.33	76.41
$V_2 \times T_2$	1.52	3.31	1.14	44.33	25.91
$V_2 \times T_3$	1.57	3.13	1.05	53.00	39.46
$V_2 \times T_4$	1.62	3.18	1.06	61.67	59.28
$V_2 \times T_5$	1.63	3.20	1.09	64.00	63.88
$V_2 \times T_6$	1.65	3.29	1.13	67.33	69.65
$V_2 \times T_7$	1.57	3.10	0.99	49.33	35.53
$V_2 \times T_8$	1.55	3.07	0.95	49.00	33.02
$V_2 \times T_9$	1.60	3.36	1.18	59.00	53.15
$V_2 \times T_{10}$	1.61	3.42	1.21	60.67	57.23
$V_2 \times T_{11}$	1.58	3.33	1.17	56.67	48.49
$V_2 \times T_{12}$	1.58	3.16	1.00	55.67	44.81
$V_2 \times T_{13}$	1.52	2.94	0.91	40.67	21.83
S. Em±	0.10	0.07	0.03	0.98	0.94
C.D. at 5%	0.29	N/A	N/A	2.80	2.69

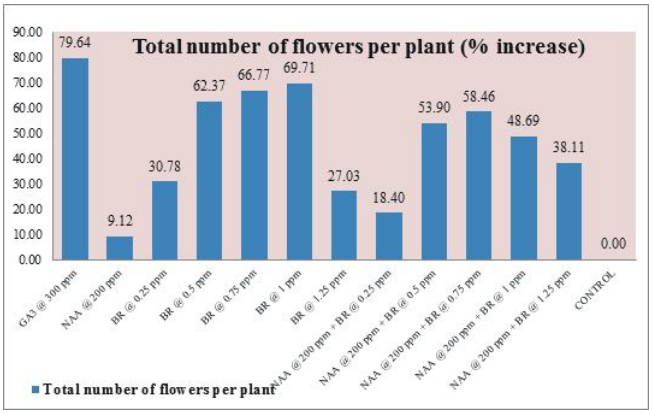


Fig. 5 : Effect of plant growth regulators on percent increase of total number of flowers per plant as compared to Control.

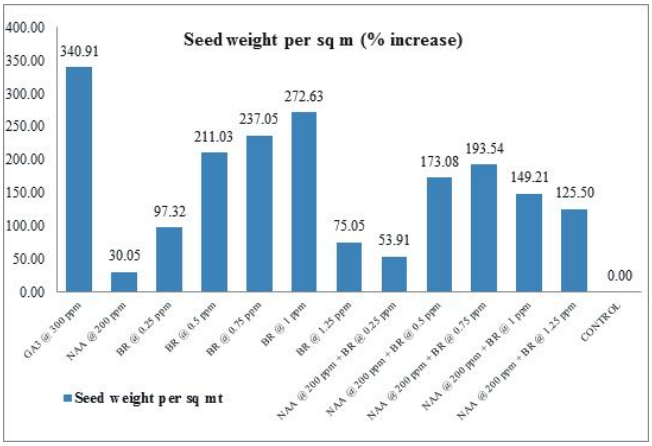


Fig. 6 : Effect of plant growth regulators on percent increase of weight of seeds per square meter as compared to Control.

found that application of GA_3 @ 300 ppm gave the best results among all the treatments. Gibberellic acid can promote seed germination by breaking seed dormancy. Dormancy is a state in which seeds do not germinate even under favourable conditions, often due to physiological or physical barriers. GA_3 can help overcome this dormancy by stimulating the synthesis of enzymes that degrade or weaken the seed coat or other barriers which allowing water and nutrients more easily to enter into the seeds. This process can lead to quicker and more uniform germination, which contributes to seed viability. The amount of water present within a seed is referred as seed moisture content. It is a critical component that influences seed viability, germination and overall quality of seed. Maintaining the proper moisture content in seeds is essential for their long-term storage and successful germination. The highest moisture content (7.67%) in the seeds was found with the treatment GA_3 @ 300 ppm and minimum (4.37%) was observed with the treatment NAA @ 200 ppm + BR @ 0.75 ppm after drying in Hot air oven. If seeds are too dry, they may become brittle and lose viability. On the other hand, if they are too moist, they can be susceptible to mold, fungal growth and premature germination, which can reduce their quality.

Conclusion

The plant growth regulators namely Gibberellic acid (GA_3), Naphthalene acetic acid (NAA) and Brassinosteroids (BR) have been used in different doses in the form of spraying singly or in combination at different stages of the plant growth. Among the three plant growth regulators, BR was the new one. BR has a unique growth promoting nature which influenced proper growth and development of China aster. But in the experiment the best results were found when GA_3 @ 300 ppm was applied at the growth stage of 45 and 60 days after transplanting for qualitative and quantitative produces of China aster. When BR applied in a range of 0.5-1 ppm along with NAA @ 200 ppm sprayed twice during the plant growth period resulted the nearest performance to the GA_3 @ 300 ppm. Due to the steroidal activities of BR it requires a little dose for their proper activities as compared to the other plant growth regulators, which indicated the less input cost for commercial cultivation of China aster in this region. The important end products of China aster are flowers (loose as well as cut flower) and seeds. The best quality flowers and seeds were found when China aster plants treated with GA_3 @ 300 ppm.

Recommendation

Among the various plant growth regulator treatments and cultivars evaluated, application of Gibberellic acid (GA_3) at 300 ppm along with the cultivar Arka Shashank was found to be most suitable for achieving superior qualitative and quantitative production of China aster under the Terai regions of West Bengal.

References

Aklade, S.A., Bardhan K., Singh P., Kakade D.K. and Pathan A. B. (2009). Effect of PGR's on growth, flowering and flower yield of chrysanthemum (*Chrysanthemum indicum* L.) cv. Local White. *Asian J. Hortic.*, **4(2)**, 491-493.

Ali, B., Hasan S.A., Hayat S., Hayat Q., Yadav S., Fariduddin Q. and Ahmad A. (2008). A role of brassinosteroids in the amelioration of aluminium stress through antioxidant system in mung bean (*Vigna radiata* L. Wilczek). *Environ. Exp. Bot.*, **62**, 153-159.

Ali, B., Hayat S. and Ahmad A. (2007). 28-Homobrassinolide ameliorates saline stress in chickpea (*Cicer arietinum* L.). *Environ. Exp. Bot.*, **59**, 217-223.

Bhandari, R., Bohra M., Singh K.C. and Bisht A.S. (2022). Effect of different plant growth regulators on seed germination and growth performance of China aster (*Callistephus chinensis* L. Nees) var. Kamini. *Int. J. Curr. Microbiol.*

Appl. Sci., **11(2)**, 297-305.

Chettri, S., Sarkar I., Sarkar D., Chakrabarty A., Dutta P. and Khan A.M. (2025). Effect of plant growth regulators on quality attributes of growth, development and yield of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda. *Agric. Sci. Dig*., 1-6.

Clouse, S.D. and Sasse J.M. (1998). Brassinosteroids: Essential regulators of plant growth and development. *Annu. Rev. Plant Biol*., **49(1)**, 427-451.

Doddagoudar, S.R., Vyakaranahal B.S., Shekhargouda M., Naliniprabhakar A.S. and Patil V.S. (2002). Effect of mother plant nutrition and chemical spray on growth and seed yield of China aster cv. Kamini. *Seed Res*., **30(2)**, 269-274.

Hewitt, F.R., Hough T., Sasse J.M. and Rowan K.S. (1985). Effect of brassinolide and other growth regulators on the germination and growth of pollen tubes of *Prunus avium* using a multiple hanging-drop assay. *Aust. J. Plant Physiol*., **12(2)**, 201-211.

Kewalanand, K., Singh J.N. and Pandey C.S. (1998). Effect of plant growth regulators on the growth, herbage and oil yield of Japanese mint (*Mentha arvensis*) and its economics therefrom. *J. Med. Aromat. Plant Sci*., **20(3)**, 725-730.

Kumar, K.P., Padmalatha T., Pratap M. and Reddy S.N. (2015). Effect of plant bio-regulators on growth, flowering and seed yield in China aster (*Callistephus chinensis* L. Nees) cv. Kamini. *Indian J. Agric. Res*., **49(4)**, 348-352.

Kumar, S., Singh A.K., Singh A. and Singh A. (2018). Effect of plant growth regulators on growth and flowering characters of China aster (*Callistephus chinensis* L. Nees) cv. Ostrich Feather. *J. Pharmacogn. Phytochem*., **7(2)**, 3149-3153.

Lakshmi, R.N., Reddy M.L., Dorajee Rao A.V.D., Bhagavan B.V.K., Subbaramamma P. and Uma Krishna K. (2021). Influence of brassinosteroids, jasmonic acid and chlorocholine chloride on yield and economics of tuberose cv. Prajwal. *J. Pharmacogn. Phytochem*., **10(2)**, 1141-1145.

Mujadidi, A., Kumar M., Malik S., Prakash S., Singh B., Singh M.K. and Chaudhary V. (2019). Effect of time and concentrations of gibberellic acid application on growth and flowering of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda. *Prog. Agric*., **19(2)**, 293-297.

Munikrishnappa, P.M. and Chandrashekar S.Y. (2014). Effect of growth regulators on growth and flowering of China aster [*Callistephus chinensis* (L.) Nees]: A review. *Agric. Rev*., **35(1)**, 57-63.

Murugan, V.T., Manivannan K. and Nanthakumar S. (2020). Studies on the effect of plant growth regulators on growth, flowering and xanthophyll content of African marigold (*Tagetes erecta* L.). *Int. J. Curr. Microbiol. Appl. Sci.*, **9(11)**, 3767-3771.

Navalinskien, M., Samuitien M. and Jomantiene R. (2005). Molecular detection and characterization of phytoplasma infecting *Callistephus chinensis* plants in Lithuania. *Phytopathol. Pol*., **35**, 109-112.

Nemhauser, J.L., Mockler T.C. and Chory J. (2004). Interdependency of brassinosteroid and auxin signaling in Arabidopsis. *PLoS Biol*., **2(9)**, e258.

Nolan, T.M., Vukašinović N., Liu D. and Yin Y. (2020). Brassinosteroids: Multidimensional regulators of plant growth, development and stress responses. *Plant Cell*, **32(2)**, 295-318.

Parmeshwar, M.K.N. (2017). Evaluation of China aster hybrids (*Callistephus chinensis* (L.) Nees.). *Doctoral Dissertation*, Mahatma Phule Krishi Vidyapeeth.

Patil, D., Chopde N., Kedar D., Gawande M. and Shinde M. (2014). Growth, flowering and seed yield of African marigold as influenced by growth regulators. *J. Soils Crops*, **24(1)**, 115-118.

Sarkar, D. (2023). Indian floriculture in global perspective. *Int. J. Plant Soil Sci*., **35(14)**, 228-238.

Shukla, A. and Farooqi A.H. (1990). Utilization of plant growth regulators in aromatic plant production. *Curr. Res. Med. Aromat. Plants*, **12(1521)**, 57.

Sindhuja, M. and Prasad V.M. (2018). Effect of different plant growth regulators and their levels on vegetative growth, floral yield and vase life of China aster (*Callistephus chinensis* L. Nees) cv. Shashank. *J. Pharmacogn. Phytochem.*, **7(6)**, 1490-1492.

Singh, A.K. (2004). Influence of plant bio-regulators on growth and seed yield in French marigold (*Tagetes patula* L.). *J. Ornam. Hortic.*, **7(2)**, 192-195.

Swaroop, K., Singh K.P. and Raju D.V.S. (2007). Vegetative growth, flowering and seed characters of African marigold (*Tagetes erecta* L.) as influenced by different growth substances during mild off seasons. *J. Ornam. Hortic.*, **10(4)**, 268-270.

Vijayakumar, S., Rajadurai K.R. and Pandiyaraj P. (2017). Effect of plant growth regulators on flower quality, yield and postharvest shelf life of China aster (*Callistephus chinensis* L. Nees) cv. Local. *Int. J. Agric. Sci. Res*., **7(2)**, 297-304.