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Effect of plant growth regulators and calcium nitrate on growth, flowering and yield of China aster

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Abstract

A field investigation was conducted during the rabi seasons of 2023-24 and 2024-25 at the Department of Floriculture and Landscaping, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, to evaluate the effect of foliar application of plant growth regulators and calcium nitrate on growth, flowering and yield of China aster (*Callistephus chinensis* (L.) Nees.) cv. Phule Ganesh White. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications and two factors, comprising 21 treatment combinations. Factor-A consists of seven levels of plant growth regulator treatments, namely water spray (control), gibberellic acid (GA₃) at 200 and 250 ppm, salicylic acid at 100 and 150 ppm, and brassinolide at 1.0 and 1.5 ppm, were evaluated in combination with factor-B consists of three calcium nitrate levels (water spray, 1.0% and 1.5%). Foliar applications were carried out at 30 and 50 days after transplanting.

The pooled results of two experimental years revealed that GA₃ at 250 ppm recorded the maximum plant height. In contrast, GA₃ at 200 ppm significantly enhanced the number of branches per plant, plant spread and leaf area. The same treatment also promoted earlier flower bud initiation, reduced the number of days required for 50% flowering, advanced first flower harvesting, extended the flowering duration, increased flower yield per plot and flower yield per ha. Among the calcium nitrate treatments, foliar application of 1.0% calcium nitrate proved superior to the control and 1.5% calcium nitrate for all vegetative growth and flowering parameters.

A significant interaction between plant growth regulators and calcium nitrate was observed for the majority of the characters studied. The treatment combination of GA₃ at 250 ppm with 1.0% calcium nitrate (G₃C₂) produced the tallest plants, whereas GA₃ at 200 ppm combined with 1.0% calcium nitrate (G₂C₂) recorded the highest number of branches, maximum flower yield.

Keywords: Brassinolide, calcium nitrate, *Callistephus chinensis*, flowering, gibberellic acid, growth, salicylic acid

Introduction

Floriculture has emerged as one of the fastest-growing sectors of horticulture due to the increasing demand for ornamental plants in domestic and international markets. In India, the expansion of commercial flower cultivation has been supported by favourable agro-climatic conditions, increasing consumer demand, and growing export opportunities (De *et al.*, 2020) [5]. Among ornamental crops, China aster (*Callistephus chinensis* (L.) Nees.) is an important annual flower belonging to the family Asteraceae. It is widely cultivated for cut flowers, loose flowers, garlands, bouquets, bedding and landscape planting because of its attractive flower colours, long flowering period and good keeping quality (Verma *et al.*, 2021) [16].

About 316.91 thousand hectares of the area were under cultivation for floriculture in 2023-24. Production of flowers is estimated to be 2658.79 thousand tonnes of loose flowers and 876.52 thousand tonnes of cut flowers and India exported 21024.41 MT floriculture products to the world for the worth of Rs. 749.17 crores. (APEDA, 2024) [1]. The productivity and quality of China aster are greatly influenced by vegetative growth and flowering behaviour. However, poor plant vigour, delayed flowering and suboptimal flower yield remain important constraints in commercial cultivation, highlighting the need for improved crop management practices (Wani *et al.*, 2023) [18].

Plant growth regulators play a vital role in regulating physiological processes such as cell division, cell elongation, photosynthesis and floral initiation. Gibberellic acid (GA₃),

salicylic acid (SA) and brassinolide (BL) have been reported to improve plant growth, flowering and flower quality in ornamental crops (Munikrishnappa and Chandrashekar, 2014) [13].

Calcium nitrate is an important source of calcium and nitrate nitrogen, which are essential for cell wall development, membrane stability, chlorophyll synthesis and overall plant growth. Foliar application of calcium nitrate has been reported to improve flower quality and post-harvest performance in ornamental crops (He *et al.*, 2020) [8]. Although the individual effects of plant growth regulators and calcium nutrition have been widely studied, information on their combined influence on China aster under the agro-climatic conditions of the Vidarbha region is limited (Mohammed and Abood, 2020) [12]. Therefore, the present investigation was undertaken to evaluate the individual and interactive effects of gibberellic acid, salicylic acid, brassinolide and calcium nitrate on the growth, flowering and yield of China aster (*Callistephus chinensis* (L.) Nees.) cv. Phule Ganesh White.

Materials and Methods

The experiment was conducted over two consecutive rabi seasons, October 2023 to March 2024 and October 2024 to March 2025, at the Department of Floriculture and Landscaping, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

The trial was laid out in a factorial randomized block design with three replications and two factors. Factor A consists seven plant growth regulator treatments: a water-sprayed control (G₁), gibberellic acid at 200 ppm (G₂) and 250 ppm (G₃), salicylic acid at 100 ppm (G₄) and 150 ppm (G₅), and brassinolide at 1.0 ppm (G₆) and 1.5 ppm (G₇). Factor B consists of three calcium nitrate levels: a water spray (C₁), 1.0% Ca(NO₃)₂ (C₂) and 1.5% Ca(NO₃)₂ (C₃) with 21 treatment combinations. Both treatments were applied as foliar sprays at 30 and 50 days after transplanting.

Seedlings of cv. Phule Ganesh White were raised in polytrays under a polyhouse; seed was sown on 20 September and treated with carbendazim before sowing. One-month-old, uniform and healthy seedlings were transplanted on 20 October of each year at a spacing of 30 × 30 cm on flat beds, with a gross plot of 1.5 × 1.8 m and a net plot of 1.2 × 1.5 m accommodating thirty plants. Farmyard manure at 10 t ha⁻¹ was incorporated at final harrowing, and the recommended fertilizer dose of 150: 50: 50 kg N: P: K ha⁻¹ was supplied through urea, single super phosphate and muriate of potash; the full P and K and half the N were applied at transplanting, with the remaining N top-dressed at 30 days. A single pinch was given at 20 days after transplanting, and irrigation, weeding and protective plant-protection sprays were carried out as needed.

Five randomly chosen, tagged plants per plot were used to record observations. Growth parameter comprised plant height (measured at 30, 45, 60, 75 and 90 DAT), number of branches per plant (measured at 60 and 75 DAT), plant spread and leaf area at 50% flowering. Leaf area determined by an automatic leaf area meter. Flowering was recorded as days to emergence of the first flower bud, days to 50% flowering, days to first harvest and duration of flowering and yield parameter was recorded as flower yield per plot and flower yield per hectare.

Results and Discussion

The results of the present investigation are presented based on the pooled mean data of two years (2023-24 and 2024-25).

Growth parameter

Effect of plant growth regulators

Both factors significantly influenced vegetative growth, and the responses were consistent across the two seasons (Table 1). In the pooled analysis, plant height increased steadily up to 90 DAT and was greatest under gibberellic acid at 250 ppm (45.45, 68.21, 78.30 and 84.51 cm at 45, 60, 75 and 90 DAT, respectively), remaining statistically at par with 200 ppm (82.79 cm at 90 DAT), while the control was the shortest throughout (67.28 cm at 90 DAT). The taller plants under gibberellic acid reflect its well-known role in stimulating cell division and elongation and in raising cell-wall extensibility, which lengthen internodes and enhance shoot growth. The findings of the present investigation are in close agreement with those reported by Vijayakumar *et al.*, (2017) [17] and Hande *et al.*, (2022) [7]. Similar result also results were observed in Mishra *et al.*, (2018) in African marigold and Kumari *et al.*, (2023) in chrysanthemum.

For the remaining growth parameter (Table 1). Gibberellic acid at 200 ppm produced the most branches per plant (12.12 at 60 DAT and 18.71 at 75 DAT), the widest plant spread (34.25 cm) and the largest leaf area (80.78 cm²), each significantly ahead of the other plant growth regulators, except in leaf area which was at par with gibberellic acid 250 ppm (78.27 cm²). Whereas the control recorded the lowest values (8.24 branches, 28.03 cm spread and 61.38 cm² leaf area). The wider canopy and greater leaf area at the moderate hormone level indicate enhanced cell division, better chlorophyll formation and more efficient assimilate movement, while the higher dose appears to divert resources preferentially into stem elongation. The findings of the present investigation are in close agreement with those reported by Vijayakumar *et al.*, (2017) [17], Sindhuja *et al.*, (2018) [15] and Hande *et al.*, (2022) [7] in China aster and also similar results were observed by Dalal *et al.*, (2009) [4] in chrysanthemum and Wani *et al.*, (2023) [18] in African marigold.

Effect of calcium nitrate

Calcium nitrate at 1.0% significantly improved all growth parameters compared to the control and 1.5% calcium nitrate; pooled plant height reached 77.75 cm at 90 DAT, 16.88 branches at 75 DAT, plant spread 32.61 cm and leaf area 72.92 cm² at this concentration. The gain is attributable to the combined action of readily available nitrate nitrogen, which supports chlorophyll and protein synthesis and calcium, which strengthens cell walls and stabilises membranes. Comparable benefits of calcium nitrate have been reported by Watane *et al.*, (2022) [19] in China aster and by Indira (2011) [9] in chrysanthemum.

Interaction effect

The interaction was significant for plant height and branching: gibberellic acid at 250 ppm with 1.0% calcium nitrate (G₃C₂) produced the tallest plants (88.64 cm at 90 DAT, pooled), whereas gibberellic acid at 200 ppm with 1.0% calcium nitrate (G₂C₂) was best for branching (13.84 at 60 DAT). However, interaction effect in plant spread at 50% flowering and leaf area was found to be non significant

(Table 1.1). The combined influence of these physiological processes likely improved photosynthetic efficiency, nutrient assimilation, and translocation of assimilates towards actively growing part of plants, resulting in a maximum height, number of branches per plant. The relatively poor performance of the control combinations could be attributed to the absence of exogenous growth regulators and additional nutrient supplementation, which limited vegetative growth.

Flowering parameter

Effect of plant growth regulators

The flowering parameters were significantly influenced by both factors. (Table 2). Among the growth regulators, gibberellic acid at 200 ppm brought the earliest emergence of the first flower bud (64.67 days pooled), the fewest days to 50% flowering (80.42 days), the earliest first harvest (83.09 days) and the longest flowering duration (46.93 days), while the control was consistently the latest to flower (72.94, 89.73 and 96.65 days, respectively) and had the shortest flowering span (38.37 days). Early flowering under gibberellic acid reflects its promotion of meristematic activity and a faster transition to the reproductive phase, and the extended flowering period points to sustained metabolic activity and a steady supply of carbohydrates to developing shoots. These results are in close agreement with Chandrashekar *et al.* (2014) [3] and Hande *et al.* (2022) [7] in China aster.

Effect of calcium nitrate

Calcium nitrate at 1.0% also advanced flowering, giving the fewest days to bud emergence (67.05 days), days to 50% flowering (83.14 days), the earliest first harvest (87.57 days) and the longest flowering duration (43.94 days) compared with the other levels. The joint supply of nitrogen and calcium evidently hastened the shift to flowering while helping the plant maintain flower production over a longer window. Comparable benefits of calcium nitrate have been reported by Watane *et al.*, (2022) [19] in China aster and by Indira (2011) [9] in chrysanthemum.

Interaction effect

The interaction effect between plant growth regulators and calcium nitrate on days to bud emergence, plant spread at 50% flowering, days to first harvesting and flowering were found to be non-significant. (Table 1).

Yield parameter

Effect of growth regulators: Application of GA₃

significantly improved flower yield in China aster (Table 2). In the pooled analysis G₂ (GA₃ @ 200 ppm) recorded the highest flower yield per plot (4.02 kg), which was followed by G₃ ((GA₃ @ 200 ppm) recorded as 3.84 kg. Whereas, the lowest yield (2.26 kg) was observed under the control (G₁). G₂ produced the maximum flower yield per hectare (148.74 q), followed by G₃ (142.10 q), while the minimum yield (83.69 q) was recorded in the control. The increased flower yield under GA₃ @ 200 ppm may be attributed to enhanced cell division, cell elongation, vegetative growth, photosynthetic efficiency and efficient translocation of photosynthates to developing flowers, resulting in greater flower production and biomass accumulation. These findings are in agreement with those of Chandrashekar *et al.* (2014) [3] and Hande *et al.* (2022) [7] in China aster, Meena *et al.* (2015) [11] in African marigold and Naik and Kumar (2016) [14] in chrysanthemum.

Effect of calcium nitrate

Foliar application of calcium nitrate significantly influenced flower yield in China aster (Table 2). In the pooled analysis, C₂ (Calcium nitrate @ 1%) recorded the highest flower yield per plot (3.71 kg) and per hectare (137.23 q), which was significantly superior to the remaining treatments. It was followed by C₃, with 3.28 kg per plot and 121.64 q per hectare, whereas the lowest flower yield was recorded under the control (C₁) (3.05 kg per plot and 112.89 q per hectare). The higher flower yield under calcium nitrate @ 1% may be attributed to the combined role of nitrogen and calcium in enhancing vegetative growth, photosynthetic activity, nutrient uptake and assimilate translocation, thereby promoting better flower development and increased yield. Similar findings were reported by Watane *et al.* (2022) [19] in China aster and Indira (2011) [9] in chrysanthemum.

Interaction effect

The interaction between plant growth regulators and calcium nitrate significantly influenced flower yield in China aster (Table 2). In the pooled analysis, the treatment combination G₂ × C₂ (GA₃ @ 200 ppm + Calcium nitrate @ 1%) recorded the highest flower yield per plot (4.57 kg) and per ha. (169.24 q), followed by G₃ × C₂ (4.33 kg and 160.49 q), whereas the lowest yield was recorded under G₁ × C₁ (1.92 kg per plot and 70.99 q per ha.). The superior performance of G₂ × C₂ may be attributed to the synergistic effect of GA₃ and calcium nitrate, which enhanced vegetative growth, photosynthetic efficiency, nutrient uptake and assimilate translocation, resulting in improved flower development and higher flower yield.

Table 1: Effect of plant growth regulators and calcium nitrate on growth parameter of China aster at different growth stages (pooled data of 2023-24 and 2024-25)

Treatments	Plant height (cm)					Number of Branches	Number of Branches	Plant spread (cm)	Leaf area (cm²)
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	(60 DAT)	(75 DAT)		
Factor A- Plant growth regulators (G)									
G ₁ - Control	21.08	30.43	52.18	61.40	67.28	8.24	13.07	28.03	61.38
G ₂ - GA ₃ (200 ppm)	21.29	43.18	66.51	76.34	82.79	12.12	18.71	34.25	80.78
G ₃ - GA ₃ (250 ppm)	21.62	45.45	68.21	78.30	84.51	11.35	17.83	32.84	78.27
G ₄ - SA (100 ppm)	20.75	34.71	55.08	63.90	70.76	10.54	15.82	31.20	67.13
G ₅ - SA (150 ppm)	21.50	35.33	55.44	64.78	71.53	9.80	15.13	30.24	66.46
G ₆ - BL (1.0 ppm)	20.85	37.00	57.89	67.33	74.78	10.76	16.41	31.99	73.45
G ₇ - BL (1.5 ppm)	20.92	39.50	61.8	71.17	78.14	10.62	16.28	31.65	70.16
'F' test	NS	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SE (m) ±	0.46	0.44	0.59	0.69	0.61	0.18	0.29	0.45	0.95
CD at 5%	-	1.26	1.7	1.97	1.75	0.51	0.82	1.29	2.71

Factor B - Calcium nitrate (C)									
C1- Control	21.12	36.1	57.48	66.73	73.12	10.05	15.45	30.14	69.00
C2 - 1% Ca(NO ₃) ₂	21.23	39.55	61.64	71.15	77.75	11.04	16.88	32.61	72.92
C3 - 1.5% Ca(NO ₃) ₂	21.08	38.18	59.64	69.20	76.19	10.37	16.20	31.62	71.35
'F' test	NS	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SEm ±	0.30	0.29	0.39	0.45	0.40	0.12	0.19	0.29	0.62
CD at 5%	-	0.82	1.11	1.29	1.15	0.33	0.54	0.84	1.77

Table 1.1: Interaction effect of plant growth regulators and calcium nitrate on growth parameter of China aster at different growth stages (pooled data of 2023-24 and 2024-25)

Treatments	Plant Height (cm)					Number of Branches per plant		Plant spread at	Leaf area at 50%
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	(60 DAT)	(75 DAT)	50% flowering (cm)	flowering (cm ²)
Interaction effect (G x C)									
G ₁ C ₁	21.76	29.45	50.44	60.17	63.63	8.23	13.06	26.05	59.96
G ₁ C ₂	20.89	31.00	53.47	61.98	69.08	8.29	12.88	29.27	61.90
G ₁ C ₃	20.58	30.84	52.62	62.06	69.14	8.20	13.29	28.79	62.28
G ₂ C ₁	21.04	39.31	63.99	71.91	80.03	11.01	16.79	32.97	77.48
G ₂ C ₂	21.86	46.26	69.80	81.26	85.65	13.84	20.86	36.18	84.86
G ₂ C ₃	20.96	43.96	65.74	75.84	82.69	11.51	18.48	33.62	79.99
G ₃ C ₁	21.44	43.02	65.28	75.37	81.65	10.90	16.52	31.11	76.14
G ₃ C ₂	21.58	48.27	72.53	82.55	88.64	11.89	19.09	34.18	80.49
G ₃ C ₃	21.84	45.05	66.83	76.97	83.25	11.26	17.89	33.22	78.16
G ₄ C ₁	20.95	34.53	54.72	63.37	70.30	10.10	15.57	29.64	66.55
G ₄ C ₂	20.88	35.15	56.12	64.38	71.36	10.93	16.14	32.76	67.58
G ₄ C ₃	20.72	34.45	54.39	63.94	70.63	10.59	15.76	31.18	67.26
G ₅ C ₁	20.84	34.51	54.57	65.01	70.73	9.22	14.46	29.41	65.95
G ₅ C ₂	20.75	36.19	56.23	64.75	72.03	10.39	15.66	30.88	67.16
G ₅ C ₃	21.17	35.28	55.53	64.58	71.83	9.79	15.28	30.43	66.28
G ₆ C ₁	20.86	35.85	55.62	63.74	71.08	10.51	16.09	31.14	70.27
G ₆ C ₂	20.72	38.27	59.72	69.77	76.85	11.13	16.86	32.48	76.03
G ₆ C ₃	20.66	36.89	58.33	68.47	76.41	10.63	16.27	32.34	74.05
G ₇ C ₁	20.95	36.06	57.74	67.57	74.43	10.40	15.68	30.64	66.67
G ₇ C ₂	21.95	41.67	63.63	73.38	80.65	10.82	16.69	32.54	72.38
G ₇ C ₃	21.61	40.77	64.05	72.56	79.36	10.63	16.46	31.77	71.43
'F' test	NS	Sig	Sig	Sig	Sig	Sig	Sig	NS	NS
SE (m) ±	0.80	0.76	1.03	1.19	1.06	0.31	0.50	0.78	1.64
CD at 5%	-	2.18	2.94	3.41	3.04	0.89	1.43	-	-

Table 2: Effect of plant growth regulators and calcium nitrate on flowering and yield parameters of China aster (pooled data of 2023-24 and 2024-25)

Treatments	Days to bud emergence	Days to 50% flowering	Days to first harvest	Flowering duration (days)	Flower yield per plot (kg)	Flower yield per ha. (q)
Factor A - Plant growth regulators (G)						
G ₁ - Control	72.94	89.73	96.65	38.37	2.26	83.69
G ₂ - GA ₃ (200 ppm)	64.67	80.42	83.09	46.93	4.02	148.74
G ₃ - GA ₃ (250 ppm)	66.24	81.46	85.79	45.22	3.84	142.10
G ₄ - SA (100 ppm)	70.05	87.07	92.18	41.97	3.22	119.35
G ₅ - SA (150 ppm)	70.59	87.85	92.96	40.53	3.20	118.46
G ₆ - BL (1.0 ppm)	67.30	84.24	88.57	43.22	3.50	129.73
G ₇ - BL (1.5 ppm)	68.40	84.35	89.25	41.26	3.39	125.37
'F' test	Sig	Sig	Sig	Sig	Sig	Sig
SE (m) ±	0.41	0.57	0.83	0.46	0.03	1.25
CD at 5%	1.18	1.64	2.38	1.32	0.10	3.57
Factor B - Calcium nitrate (C)						
C1- Control	70.33	87.56	92.47	41.16	3.05	112.89
C2 - 1% Ca(NO ₃) ₂	66.26	82.1	86.17	43.94	3.71	137.23
C3 - 1.5% Ca(NO ₃) ₂	67.82	83.51	87.99	42.4	3.28	121.64
'F' test	Sig	Sig	Sig	Sig	Sig	Sig
SEm ±	0.27	0.38	0.55	0.30	0.02	0.82
CD at 5%	0.77	1.07	1.56	0.86	0.06	2.34
Interaction effect (G x C)						
G ₁ C ₁	75.21	94.23	100.41	34.90	2.13	70.99
G ₁ C ₂	71.36	87.39	94.69	40.48	2.73	87.80
G ₁ C ₃	72.26	87.57	94.86	39.72	2.77	92.27
G ₂ C ₁	67.11	84.94	87.51	45.78	3.86	128.76
G ₂ C ₂	62.20	76.83	79.52	48.85	5.06	169.24
G ₂ C ₃	64.70	79.49	82.23	46.16	4.31	148.22

G ₃ C ₁	68.75	85.38	91.02	43.53	3.66	122.14
G ₃ C ₂	64.03	78.88	81.38	46.35	4.82	160.49
G ₃ C ₃	65.94	80.12	84.99	45.78	4.44	143.69
G ₄ C ₁	70.88	89.47	94.36	41.47	3.58	116.43
G ₄ C ₂	69.07	85.51	91.29	42.65	4.14	134.92
G ₄ C ₃	70.22	86.23	90.88	41.80	3.56	106.70
G ₅ C ₁	72.39	88.40	93.28	39.33	3.57	113.49
G ₅ C ₂	69.38	87.33	92.55	41.83	4.30	126.97
G ₅ C ₃	70.01	87.81	93.05	40.42	3.81	114.94
G ₆ C ₁	68.40	85.40	89.01	42.73	3.49	119.03
G ₆ C ₂	65.89	82.71	86.99	45.07	4.05	143.22
G ₆ C ₃	67.62	84.60	89.70	41.85	3.20	126.93
G ₇ C ₁	69.60	85.14	91.68	40.36	3.41	119.41
G ₇ C ₂	67.42	83.31	86.59	42.34	3.81	137.97
G ₇ C ₃	68.19	84.61	89.48	41.09	3.45	118.72
'F' Test	NS	NS	NS	NS	Sig	Sig
SEm ±	0.71	1.19	1.44	0.80	0.06	2.17
CD at 5%	-	-	-	-	0.17	6.19

Conclusion

The findings of the present investigation demonstrated that foliar application of plant growth regulators along with calcium nitrate effectively improved the vegetative growth and flowering performance of China aster. Among the plant growth regulators evaluated, GA₃ at 250 ppm produced the tallest plants, whereas GA₃ at 200 ppm was more effective in enhancing branching, plant spread, leaf area, early flower bud initiation, earlier 50% flowering, and longer flowering duration. Application of 1.0% calcium nitrate consistently resulted in better growth and flowering than both the control and 1.5% calcium nitrate. The combined application of GA₃ at 200 ppm and 1.0% calcium nitrate (G₂C₂) showed the best overall performance and can therefore be recommended for commercial cultivation of China aster under the agro-climatic conditions of the Vidarbha region. However, if the objective is to produce taller plants, the combination of GA₃ at 250 ppm with 1.0% calcium nitrate (G₃C₂) would be a more suitable choice.

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