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IMPACT OF ORGANIC MANURES AND BIO-FERTILIZER ON GROWTH AND YIELD OF CHINA ASTER CV. POORNIMA IN UTTARAKHAND'S HIGH HILLS

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China aster (*Callistephus chinensis* L. Nees) is a half-hardy, free-blooming winter annual within the Asteraceae family, originating from China. This self-pollinating species produces solitary flowers that can be semi-double or double, with colours ranging from pink, blue, violet, to white (Bose *et al.*, 2003). In India, China aster is cultivated commercially in Karnataka, Tamil Nadu, West Bengal, and Maharashtra. Beyond India, it is also grown in China, across Europe, including France, Germany, the Netherlands, Russia, and Switzerland, as well as in Japan, North America, and the United Kingdom (Chakraborty *et al.*, 2019). Traditionally, it is used for a variety of purposes including loose and cut flowers, floral decorations, garlands, hair adornments, bouquets, buttonholes, and as a bedding plant. Additionally, it is cultivated as a pot plant and used in mixed herbaceous borders.

China aster is a winter annual crop well-adapted to a range of agro-climatic conditions. Optimal flower coloration occurs when daytime temperatures range between 20-30°C and nighttime temperatures between 15-17°C. The crop thrives in well-drained red loamy soils with a pH of 6.8-7.5. Its ease of cultivation and relatively short growth period contribute to its popularity among growers. However, to achieve higher yields in a shorter time, many growers resort to applying large quantities of chemical fertilizers. This practice has been shown to have detrimental effects on both flora and fauna (Bohra and Nautiyal, 2019). Excessive and continuous use of chemical fertilizers not only escalates input costs but also leads to soil fertility depletion and reduced productivity (Sharma *et al.*, 2017). Pradhan *et al.* (2018) further highlighted that the long-term use of chemical fertilizers adversely impacts ecosystem and soil health. Therefore, the adoption of integrated nutrient management, combining both organic and inorganic fertilizers, is essential for sustainable crop production.

The Integrated Nutrient Management (INM) approach effectively reduces the reliance on chemical fertilizers by maximizing the use of biological inputs. Ranjan and Bohra (2023) demonstrated that a combination of 75% recommended dose of fertilizers (RDF) with 25% vermicompost, Azotobacter (2 mL/L), and phosphorus solubilizing bacteria (PSB) (2 mL/L) significantly enhanced the growth, yield, and economic returns of African marigold. INM involves the strategic use of a balanced mix of organic and inorganic fertilizers along with specific microorganisms to increase nutrient availability to plants, ultimately leading to higher yields. This method is a viable option for maintaining optimal soil fertility and productivity (Satapathy *et al.*, 2016).

Organic manures such as farmyard manure (FYM), vermicompost, poultry, sheep, and goat manures, and compost decompose slowly, providing a steady supply of nutrients throughout the plant growth cycle. Hazarika *et al.* (2014) found that the application of organic manures not only enhances nutrient availability but also improves soil physical properties and pH. Biofertilizers, which contain live microorganisms capable of converting nutrients into more accessible forms through biological processes, further increase nutrient efficiency (Bhati *et al.*, 2018). The application of biofertilizers has been shown to boost crop yields by 10 to 30 percent (Mahala *et al.*, 2019). Given their cost-effectiveness, sustainability, and commercial viability, INM presents a promising approach for enhancing flower production. Therefore, in light of these benefits, a comprehensive study was undertaken to evaluate the impact of various INM packages on the flower production of China aster cv. Poornima.

The study was conducted at the Demonstration and Research Block of the College of Horticulture, Veer Chandra Singh Garhwali, Uttarakhand University of Horticulture and Forestry, Bharsar, District Pauri Garhwal, Uttarakhand, India. The experimental site is located in the high hills of the Himalayas at an altitude of 1900 meters above sea level, with coordinates of 29°20'-29°75' N latitude and 78°10'-78°80' E longitude. During the investigation, the average maximum temperature ranged from 15 to 27°C. The soil at the site was sandy loam, well-drained, and slightly acidic, with a pH ranging from 4.44 to 5.51 and an electrical conductivity (EC) of 0.49 dS/m. Initial soil tests recorded available nitrogen, phosphorus, and potassium levels of 331.20 kg/ha, 18.07 kg/ha, and 129.02 kg/ha, respectively.

The experiment employed a randomized complete block design with fourteen treatments, replicated three

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times. The treatments were as follows: T_1: Control, T_2: 100% RDF (180:120:60 kg/ha), T_3: 75% RDF + 25% N FYM, T_4: 50% RDF + 50% N FYM, T_5: 25% RDF + 75% N FYM, T_6: 75% RDF + 25% N Vermicompost, T_7: 50% RDF + 50% N Vermicompost, T_8: 25% RDF + 75% N Vermicompost, T_9: 75% RDF + 25% N FYM + Azotobacter (2 mL/L) + PSB (2 mL/L), T_{10}: 50% RDF + 50% N FYM + Azotobacter (2 mL/L) + PSB (2 mL/L), T_{11}: 25% RDF + 75% N FYM + Azotobacter (2 mL/L) + PSB (2 mL/L), T_{12}: 75% RDF + 25% N Vermicompost + Azotobacter (2 mL/L) + PSB (2 mL/L), T_{13}: 50% RDF + 50% N Vermicompost + Azotobacter (2 mL/L) + PSB (2 mL/L) and T_{14}: 25% RDF + 75% N Vermicompost + Azotobacter (2 mL/L) + PSB (2 mL/L).

In these treatments, 'N' represents the nitrogen dose supplied through FYM (farmyard manure) and vermicompost, compensating for reduced RDF doses. Each plot measured 120 cm x 120 cm and accommodated 16 plants, with seedlings of uniform size (2-3 leaves stage) planted in the evening at a spacing of 30 cm x 30 cm. Farmyard manure and vermicompost were applied 15 days before transplanting. Inorganic fertilizers used included urea, single super phosphate, and potassium. Half of the nitrogen and the full doses of phosphorus and potassium were applied as a basal dose during field preparation, while the remaining half of the nitrogen was applied 30 days after planting. Biofertilizers, Azotobacter and PSB, were sourced from Karnataka Agro Chemicals Ltd. and applied according to the company's recommendations. Seedlings were dipped in biofertilizer solutions for 30 minutes before transplanting. Observations on various vegetative and floral attributes were recorded and analyzed statistically using OPSTAT software at a 5% significance level, following the methods outlined by Gomez and Gomez (1984).

Vegetative attributes

The data presented in Table 1 indicate that the highest plant height (79.54 cm) was achieved with treatment T_{13}, followed by T_{12} (77.25 cm), while the shortest plants were observed in the control treatment T_1 (56.57 cm). The observed increase in plant height with these treatments can be attributed to the optimal availability of nutrients provided by both organic and inorganic sources. Kumar *et al.* (2011) reported that vermicompost supplies essential macro (N, P, K) and micronutrients (Zn, Fe, Cu, Mn), along with enzymes

Table 1. Effect of integrated nutrient management on vegetative and floral attributes of China aster cv. Poornima at full bloom stage

Treatment	Plant height (cm)	No. of primary branches per plant	Plant spread (cm)	No. of leaves per plant	Number of days taken to first flower bud appearance	Duration of flowering (days)
T_1	56.57	12.46	15.43	210.80	79.90	17.36
T_2	76.34	21.26	29.00	357.06	70.43	26.16
T_3	64.30	16.23	21.70	248.06	78.86	20.66
T_4	65.58	16.06	21.26	230.83	79.16	19.16
T_5	60.56	14.93	19.66	221.03	79.86	18.03
T_6	70.69	17.13	22.13	256.76	75.16	21.10
T_7	69.58	16.96	22.00	248.53	76.56	20.30
T_8	59.78	15.83	20.70	263.76	79.56	18.60
T_9	74.71	21.06	24.80	353.86	74.93	22.26
T_{10}	73.23	19.66	24.56	328.70	71.73	24.46
T_{11}	68.80	17.50	22.70	290.26	72.96	24.00
T_{12}	77.25	23.66	31.30	376.53	71.26	25.53
T_{13}	79.54	21.66	30.03	367.30	68.60	26.83
T_{14}	71.12	18.66	24.53	301.40	73.63	23.43
S.E.(d)	1.07	1.16	1.65	3.93	1.01	1.36
CD ($p \leq 0.05$)	2.22	2.40	3.41	8.12	2.09	2.82

T_1: Control, T_2: 100% RDF, T_3: 75% RDF + 25% 'N' Farmyard manure, T_4: 50% RDF + 50% 'N' Farmyard manure, T_5: 25% RDF + 75% 'N' Farmyard manure, T_6: 75% RDF + 25% 'N' Vermicompost, T_7: 50% RDF + 50% 'N' Vermicompost, T_8: 25% RDF + 75% 'N' Vermicompost, T_9: 75% RDF + 25% 'N' Farmyard manure + *Azotobacter* (2mL/L) + PSB (2 mL/ L), T_{10}: 50% RDF + 50% 'N' Farmyard manure + *Azotobacter* (2 mL/L) + PSB (2 mL/L), T_{11}: 25% RDF + 75% 'N' Farmyard manure + *Azotobacter* (2 mL/L) + PSB (2 mL/L), T_{12}: 75% RDF + 25% 'N' Vermicompost + *Azotobacter* (2 mL/L) + PSB (2mL/L), T_{13}: 50% RDF + 50% 'N' Vermicompost + *Azotobacter* (2 mL/L) + PSB (2 mL/L), T_{14}: 25% RDF + 75% 'N' Vermicompost + *Azotobacter* (2mL/L) + PSB (2mL/L) and growth hormones during the early growth stages, which promotes increased plant height. Additionally, phosphorus solubilizing bacteria (PSB) and Azotobacter enhance the availability of insoluble phosphorus and nitrogen through the production of organic acids (Bohra *et al.*, 2019). Thumar *et al.* (2013) found that the combination of 70% RDF with vermicompost (2 t/ha), Azotobacter, Azospirillum, and PSB resulted in the maximum plant height in marigold. Similar improvements in plant height have also been reported by Kumar *et al.* (2013) in marigold and Patanwar *et al.* (2014) in chrysanthemum.

The data presented in Table 1 show that the highest number of primary branches per plant (23.66) and the greatest plant spread (31.30 cm) were observed in treatment T_{12}. These results were statistically comparable to those of T_{13} (21.66 branches and 30.03 cm spread) and T_2 (21.26 branches and 29.00 cm spread). The beneficial effects of vermicompost and bio-fertilizers, in combination with inorganic fertilizers, likely promoted cell multiplication, enlargement, and differentiation, leading to improved photosynthesis and consequently a higher number of branches and greater plant spread. Nitrogen, being a key component of nucleic acids, enhances the synthesis of carbohydrates, amino acids, and phytohormones such as auxins, gibberellins, and cytokinins. Phosphorus, an essential component of protoplasm and chlorophyll, facilitates the conversion of photosynthates into phospholipids, thereby promoting vegetative growth (Singh *et al.*, 2017). These findings are consistent with previous research by Naik and Dalawa (2014) in carnations, Patanwar *et al.* (2014) in chrysanthemums, and Khanna *et al.* (2016) in China aster.

The data further indicate that the highest number of leaves per plant (376.53) was observed in plants treated with T_{12}, while the lowest count (210.80) was recorded in the control treatment (Table 1). The increase in the number of leaves per plant under T_{12} can be attributed to the higher number of branches and greater plant spread associated with this treatment, which naturally leads to an increased leaf count. These findings are consistent with those of Ranjan and Bohra *et al.* (2023), who reported that marigold plants receiving 75% RDF combined with 25% vermicompost, Azotobacter, and PSB (each at 2 mL/L) exhibited the highest number of leaves per plant.

Table 2. Effect of Integrated Nutrient Management (INM) on flower quality and yield attributes of China aster cv. Poornima

Treatment	Flower diameter (cm)	Individual Flower weight (g)	Stalk length (cm)	Shelf life (days)	Vase life (days)	Number of flowers per plant	Number of flowers per plot	Flower yield per plant (g)	Flower yield per plot (kg)	% increase in flower yield per plant
T_1	5.43	3.63	24.16	3.00	5.90	22.56	360.70	81.93	1.30	-
T_2	6.86	5.20	37.63	4.80	7.90	32.46	519.70	151.36	2.25	84.74
T_3	5.80	4.43	26.70	4.06	6.53	29.00	464.53	130.83	2.09	59.68
T_4	5.70	4.23	26.56	3.60	6.46	28.36	453.20	129.46	2.07	58.01
T_5	5.53	4.00	24.26	3.10	6.10	23.93	382.93	124.46	1.98	51.91
T_6	6.03	4.56	27.53	4.26	6.73	30.46	487.63	134.13	2.11	63.71
T_7	5.90	4.53	26.73	4.16	6.65	29.10	465.96	132.92	2.12	62.23
T_8	5.63	4.03	25.96	3.23	6.20	27.73	443.36	129.80	2.06	58.42
T_9	6.70	4.80	33.96	4.70	7.40	32.43	518.70	150.00	2.42	83.08
T_{10}	6.66	4.70	33.40	4.56	7.20	31.60	505.23	143.73	2.40	75.43
T_{11}	6.60	4.63	32.23	4.40	6.80	30.73	491.20	137.90	2.19	68.31
T_{12}	6.73	4.96	36.56	4.73	7.86	34.53	552.53	162.26	2.59	98.04
T_{13}	7.30	5.46	38.63	4.90	8.00	33.76	540.26	156.76	2.50	91.33
T_{14}	6.63	4.66	32.63	4.53	6.90	31.26	500.46	141.43	2.29	72.62
S.E.(d)	0.52	0.45	1.44	0.50	0.43	0.90	2.78	1.70	0.29	
CD ($p \leq 0.05$)	1.09	0.93	2.98	1.04	0.90	1.86	5.74	3.53	0.61	

T_1: Control, T_2: 100% RDF, T_3: 75% RDF + 25% 'N' Farmyard manure, T_4: 50% RDF + 50% 'N' Farmyard manure, T_5: 25% RDF + 75% 'N' Farmyard manure, T_6: 75% RDF + 25% 'N' Vermicompost, T_7: 50% RDF + 50% 'N' Vermicompost, T_8: 25% RDF + 75% 'N' Vermicompost, T_9: 75% RDF + 25% 'N' Farmyard manure + *Azotobacter* (2mL/L) + PSB (2 mL/ L), T_{10}: 50% RDF + 50% 'N' Farmyard manure + *Azotobacter* (2 mL/L) + PSB (2 mL/L), T_{11}: 25% RDF + 75% 'N' Farmyard manure + *Azotobacter* (2 mL/L) + PSB (2 mL/L), T_{12}: 75% RDF + 25% 'N' Vermicompost + *Azotobacter* (2 mL/L) + PSB (2mL/L), T_{13}: 50% RDF + 50% 'N' Vermicompost + *Azotobacter* (2 mL/L) + PSB (2 mL/L), T_{14}: 25% RDF + 75% 'N' Vermicompost + *Azotobacter* (2mL/L) + PSB (2mL/L)

Floral attributes

The data presented in Table 1 indicate that all treatments significantly improved the earliness of flowering in China aster cv. Poornima compared to the control. The combination of 50% RDF, 50% nitrogen (N) vermicompost, Azotobacter (2 mL/L), and phosphorus solubilizing bacteria (PSB) (2 mL/L) resulted in the earliest bud appearance at 68.60 days. In contrast, the control treatment (T_1) recorded the longest time to bud appearance at 79.90 days.

The enhanced earliness in bud appearance can be attributed to the effective amplification of nutrients (N, P, and K) provided by the inorganic, organic, and bio-fertilizers. These nutrients likely facilitated the translocation of phytohormones to the shoots, thereby promoting earlier bud development. Additionally, the application of vermicompost improved soil microflora and enzymatic activity, which supported vigorous vegetative growth and contributed to earlier flowering (Jogi *et al.*, 2020). These observations align with the findings of Ravindra *et al.* (2013), who reported that a treatment of 50% RDF combined with vermicompost (2 t/acre), Azospirillum, and PSB (each at 2 kg/acre) also resulted in earlier flower opening in China aster.

The longest flowering duration (26.83 days) was observed with the application of T_{13}, which was statistically similar to T_2 (26.16 days), T_{12} (25.53 days), and T_{10} (24.46 days). This extended flowering period is likely attributable to the enhanced soil nutrient status provided by the integrated use of vermicompost and other nutrients. The phosphorus solubilizing bacteria (PSB) and Azotobacter contributed to the conversion of these nutrients into more readily absorbable forms, thereby increasing the availability of nutrients and water to the plants. These findings are consistent with those reported by Singh *et al.* (2017) for China aster and Kumar (2015) for chrysanthemums. The treatment with 50% RDF, 50% nitrogen (N) vermicompost, Azotobacter (2 mL/L), and PSB (2 mL/L) (T_{13}) also resulted in the highest flower diameter (7.30 cm), individual flower weight (5.46 g), and stalk length (38.63 cm) as detailed in Table 2. The improvements in flower diameter, weight, and stalk length with T_{13} can be attributed to the balanced application of inorganic fertilizers, vermicompost, Azotobacter, and PSB, which collectively enhanced nutrient uptake. Khanna *et al.* (2016) reported that adequate potassium and nitrogen are critical for achieving larger flowers. These results are supported by Kaushik and Singh (2020), who found that the application of 50% RDF combined with 50% vermicompost and Azotobacter produced the largest flower diameter and weight in marigold. Furthermore, Adhikari *et al.* (2018) observed increased spike length with the judicious use of organic and inorganic nutrients in gladiolus.

The longest shelf life (4.90 days) and vase life (8.00 days) were observed in flowers harvested from plants treated with T_{13} (50% RDF + 50% nitrogen (N) vermicompost + Azotobacter (2 mL/L) + PSB (2 mL/L)). The extended shelf and vase life can be attributed to the improved nutrient status of the flowers, resulting from the integrated application of organic and inorganic nutrient sources. This comprehensive nutrient supply enhances the development of water-conducting tissues and increases water retention within the flower cells, thereby reducing desiccation. These findings align with those of Azmeera *et al.* (2015) in African marigold and Bohra *et al.* (2019) in China aster, who also reported improvements in shelf and vase life with enhanced nutrient management.

The highest number of flowers per plant (34.53) was observed in treatment T_{12}, which was statistically similar to T_{13} (33.76). Additionally, treatment T_{12}, which comprised 75% RDF, 25% nitrogen (N) vermicompost, Azotobacter (2 mL/L), and PSB (2 mL/L), also produced the greatest number of flowers per plot (552.53), flower yield per plant (162.26 g), and flower yield per plot (2.59 kg).

The increased flower yield can be attributed to the higher number of leaves per plant and greater plant spread, which likely led to enhanced photosynthesis and accumulation of photosynthates, thus supporting the production of more flowers. Giri and Beura (2020) noted that vermicompost and biofertilizers enhance carbon assimilation, with Azotobacter aiding in atmospheric nitrogen fixation and PSB solubilizing insoluble phosphorus, making these nutrients more available to plants. Vermicompost not only provides essential macro and micro-nutrients but also boosts enzymatic activity and growth through hormone-like effects.

The results align with Bose *et al.* (2018), who found that China aster plants receiving 75% RDF combined with farmyard manure (FYM), Azospirillum, and PSB (2.5 kg/ha) had the highest number of flowers and flower yield. Similarly, Kumar *et al.* (2019) reported that the combination of 50% RDF, vermicompost, Azotobacter, and PSB resulted in the highest flower yield in China aster. The percentage increase in flower yield per plant ranged from 51.91% to 98.04% compared to the control, demonstrating that all applied treatments were significantly effective in enhancing yield. Notably, the greatest increase in flower yield per plant was recorded with T_{12}.

The results from the present investigation indicate that the application of 75% RDF, 25% vermicompost, Azotobacter (2 mL/L), and PSB (2 mL/L) was effective in enhancing the flower yield of China aster cv. Poornima.

Authors' contribution

Conceptualization of research work and designing of experiments (MB); Execution of field/lab experiments and data collection (AB); Analysis of data and interpretation (AB); Preparation of manuscript (MB)

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