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RESEARCH ARTICLE

Effect of nitrogen, phosphorus and potassium levels on growth, flowering and yield of African marigold (*Tagetes erecta* L. var. BM-2) under Odisha's climatic conditions

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Abstract

Floriculture has emerged as a successful agribusiness, enhancing land productivity and generating employment across the value chain, from cultivation to retail, ultimately boosting the incomes of farmers and business owners. The marigold (*Tagetes* spp.), a member of the Asteraceae family, is a significant loose flower that cultivated commercially worldwide. Odisha has a good capacity for production because of the appropriate soil and climatic conditions. Given its significance, learning about enhanced cultivation and technological advancements in floriculture is essential for obtaining larger harvests. BM-2 is a high-performing variety and no research on this particular variety under Odisha's climatic conditions is currently available. To address this gap, a study was conducted using 24 treatment combinations derived from different levels of nitrogen, phosphorus and potassium (0, 60, 80 and 100 kg/ha each) and two levels of farmyard manure (FYM) (5 and 10 tonnes/ha), along with one control (no fertilizer). The effects of varying nitrogen, phosphorous and potassium dosages were assessed by recording and analyzing data from each of the 24 plots of the African marigold variety BM-2 for each season. The study concluded that, for the BM-2 variety, NPK application at 100:100:100 kg/ha produced the highest flower yield, NPK application at 100:80:100 kg/ha resulted in the best floral quality and NPK application at 80:100:100 kg/ha produced the greatest number of flowers.

Keywords: African marigold; nitrogen; phosphorous; potassium; yield

Introduction

Floriculture has become a successful agribusiness because it increases land productivity, creates a wide range of jobs from grower fields to retail stores and boosts the incomes of farmers and business owners. By diversifying into other areas of agriculture and serving as a source of foreign exchange, commercial floriculture in India has gained greater legitimacy. The major loose flower crops including marigold, jasmine, chrysanthemum, rose, crossandra, tuberose and China aster can be cultivated across the Indian subcontinent due to its diverse agroclimatic conditions. Marigold ranks among the most important commercial loose flower crops and is cultivated in nearly all Indian states. Odisha offers excellent production potential due to its suitable soil and climatic conditions. Because of the high demand for flowers for religious offerings, garlands and adornment, marigolds are required daily. One of the main factors influencing marigold development and yield among the many agro-techniques is nutrition. Marigold is a fast-growing crop with a short lifespan and its root system expands steadily and swiftly. Using the proper fertilizers is therefore crucial for producing high-quality blooms and increasing yield, especially those that are high in nitrogen, phosphorus and potassium. The deficiency of these nutrients strongly inhibits the plant growth. Soil fertility is a dynamic property influenced by factors such as crop types, cropping intensity, input utilization and soil nutrient availability. More than half of the cultivated soils have organic matter levels below the required level. Farmers who apply fertilizers in the field without understanding the soil fertility status and the nutrient requirements of various crops typically cause nutrient deficiencies or toxicities in the crop due to insufficient or excessive fertilizer use.

Materials and Methods

The field study was carried out at the Biotechnology-cum-Tissue Culture Centre (BTCC), College of Agriculture, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha, from October 2019 to March 2020, November 2020 to March 2021 and November 2021 to March 2022 as part of a pooled data set. Geographically, it is located at 20.250° N latitude and 85.520° E longitude. Stem cuttings are typically used to cultivate African marigold. In September, rooted stem cuttings of the BM-2 type were taken from the AICRP on Floriculture mother plant block. Using sterilized sand media, 8-10 cm long herbaceous shoot cuttings were placed in the seed pans to initiate rooting. For better and more consistent root formation, the basal section of the cuttings was treated with Rootex powder (active ingredient: Indole-3-butyric acid) prior to planting.

All the treatments were randomized separately in each replication. Irrigation and drainage channels were laid out to facilitate efficient intercultural operations. The experimental design followed was a Randomized Block Design (RBD), as shown in Fig. 1. A total of 24 treatments were selected, with three replications each, consisting of combinations of nitrogen, phosphorus and potassium at 0, 60, 80 and 100 kg/ha along with FYM. The treatment details are presented in Table 1.

To prevent mortality, well-established marigold seedlings were placed in polybags in the field. In addition to removing undesirable items like weeds, grass, crop leftovers, foreign materials, etc., the trial field was completely ploughed. The treatments were laid out in a RBD with three replications. Plant-to-plant and row-to-row spacing was maintained at 30 cm × 30 cm. For improved plant establishment, mild irrigation was applied both before planting and immediately after transplanting. During land preparation, about a week before transplanting, well-decomposed FYM was applied into the plots where organic matter was designated for application.

Each plot received the fertilizer dosage specified by the treatment plan. At the time of transplanting, half of the nitrogen along with the full dose of phosphate and potash was applied, while the remaining nitrogen was applied one month later. Urea supplied nitrogen, single superphosphate (SSP) supplied phosphorus and muriate of potash (MOP) supplied potassium. One month after transplanting, the seedlings were pinched to promote the plants' lateral expansion. Five plants, excluding the boundary rows, were chosen at random from each treatment plot and tagged to collect data on the different characters that would be examined. Harvesting began when the first bloom reached the fully open stage and continued alternate days as subsequent flowers opened. After each harvest, the number of flowers from each tagged plant was recorded separately.

Observations on plant height, plant spread (N-S and E-W), number of primary and secondary branches per plant and stem diameter were recorded from five tagged plants in each treatment, along with data on days to flower bud appearance and opening, shelf life, flower diameter, flower weight, number of flowers per plant, weight per plant and flowering duration.

Table 1. Treatment details

Sl. No.	Treatments		
	Nitrogen (kg/ha)	Phosphorous (kg/ha)	Potassium (kg/ha)
1	0	80	80
2	60	60	60
3	60	60	80
4	60	80	60
5	60	80	80
6	80	0	80
7	80	60	60
8	80	60	80
9	80	80	0
10	80	80	60
11	80	80	80
12	80	80	100
13	80	100	60
14	80	100	100
15	60	100	80
16	100	80	60
17	100	80	80
18	100	80	100
19	80	60	100
20	80	100	80
21	100	100	100
22	No chemical, no organic		
23	5 tons FYM/ha		
24	10 tons FYM/ha		

Fig. 1. Experimental field of African marigold.

Statistical analysis

The data collected from various field observations were subjected to statistical analysis using the standard analysis of variance (ANOVA) technique (1) and the results are presented in the ANOVA table (Table 2).

Results

The analysis of all vegetative, floral and yield-attributing parameters is presented in Table 3.

Vegetative characters

The vegetative parameters included plant height, plant spread, number of primary and secondary branches and stem diameter. Maximum plant height (55.0 cm), plant spread north-south (52.67 cm), plant spread east-west (50.67 cm) and number of primary branches per plant (14) were recorded with the application of T_{18} NPK (100:80:100) and T_{21} NPK (100:100:100). The highest number of secondary branches per plant (41) was obtained with T_{21} NPK (100:100:100), while the greatest stem diameter (1.67 cm) was observed in T_{18} NPK (100:80:100). A figure of marigold plants at 45 days after transplanting is shown in Fig. 2.

Floral characters

Early flower bud appearance was observed in T_{17} NPK 100:80:100 kg/ha (58 days), which was at par with T_{21} NPK 100:100:100 kg/ha (58.33 days), T_{19} NPK 80:60:100 kg/ha (58.50 days), T_{18} NPK 100:80:100 kg/ha (58.67 days) and T_{20} NPK 80:100:80 kg/ha (58.67 days). Early flower bud opening was observed in T_{14} NPK 80:100:100 kg/ha (8.02 days), which was at par with T_{15} NPK 60:100:80 kg/ha (8.16 days) and T_{20} NPK 80:100:80 kg/ha (8.56 days).

Table 2. Analysis of Variance (ANOVA) for quantitative characters in 24 treatments of African marigold

Sl. No.	Characters	Mean square		
		Replication	Treatment	Error
	df	2	23	46
1	Plant height	3.79	41.72**	4.56
2	Plant spread (N-S)	0.72	28.74**	12.58
3	Plant spread (E-W)	18.04	4.60	8.35
4	Number of primary branches per plant	0.54	12.06**	0.73
5	Number of secondary branches per plant	1.85	97.51**	5.08
6	Stem diameter	0.15*	0.13**	0.03
7	Number of days taken for flower bud appearance	3.41	7.51	5.50
8	Number of days taken for flower bud opening	54.0	4.59	1.69
9	Shelf life of flowers	0.5	6.61**	0.30
10	Flower diameter	0.21*	0.22**	0.06
11	Flower weight	203.47**	4.10	0.26
12	Number of flowers per plant	420.38**	17.52	2.69
13	Weight of flowers per plant	9.97	560.1**	48.19
14	Duration of flowering	0.5	110.83	2.1

* Significant at 5 % level ** Significant at 1 % level

Fig. 2. Marigold plants at 45 days after transplanting.

Yield attributing characters

The largest flowers, with the highest flower diameter, were recorded in T_{12} NPK 80:80:100 kg/ha (5.60 cm). The greatest individual flower weight was found in T_{18} NPK 100:80:100 kg/ha (8.33 g), which was at par with T_{21} NPK 100:100:100 kg/ha (8.22 g). The highest number of flowers per plant was obtained in T_{20} NPK 80:100:80 kg/ha (142.52) while the longest flowering duration was observed in T_{11} NPK 80:80:100 kg/ha (90.33 days). The yield of flowers per plant was highest in T_{21} NPK 100:100:100 kg/ha (1008.31 g). A comparative picture of flower sizes is shown in Fig. 3.

Discussion

The effect of graded doses of nitrogen, phosphorus and potassium on flower yield is presented as graphs in Fig. 4-6 respectively. Higher doses of NPK were superior to the other treatments due to increased cell division, cell enlargement and enhanced conversion of photosynthates to plant growth that may have resulted from the availability of three major nutrients (2-4). These results are consistent with earlier reports on marigold (5-8). According to a previous study nitrogen is one of the most crucial nutrients for promoting plant growth and development (9). It increases photosynthesis, enhances metabolite transport and promotes cell division (10). The results of this study agreed with previous studies, which also reported that higher nitrogen dosages resulted in the maximum plant development (11-16).

One possible explanation for the delayed onset of flowering could be the conflict between the vegetative and reproductive phases, which resulted from the former's

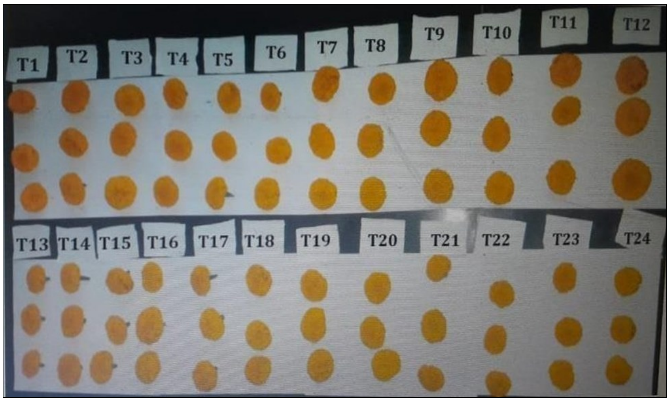

Fig. 3. Comparison of flower sizes across all treatments .

Table 3. Mean values of vegetative, floral and yield attributing characters across 24 treatments

Treatments	NPK (kg/ha)	Characters													
		Plant height	Spread N-S	Spread E-W	Primary branches	Secondary branches	Stem diameter	Bud appearance	Bud open	Flower diameter	Flower weight	Flower per plant	Duration	Shelf life	Yield per plant
T_1	0:80:80	44.00	45.33	47.67	10.00	29.00	1.53	62.33	11.62	4.67	5.27	133.18	90.00	5.33	701.40
T_2	60:60:60	44.33	46.33	48.00	10.33	30.00	1.53	62.50	11.48	5.23	5.58	135.14	87.00	4.50	754.52
T_3	60:60:80	45.00	46.33	48.33	10.67	31.00	1.33	61.33	11.59	5.03	6.22	124.63	87.33	5.00	774.77
T_4	60:80:60	45.33	46.67	48.67	10.67	31.67	1.33	59.50	10.11	5.20	6.27	126.81	87.67	4.67	794.67
T_5	60:80:80	48.00	47.67	49.00	11.00	32.00	1.40	61.0	11.50	5.00	6.42	124.02	88.00	5.00	795.82
T_6	80:0:80	47.67	47.00	48.67	10.67	31.00	1.20	59.50	10.20	5.00	5.65	131.88	88.50	5.00	745.11
T_7	80:60:60	49.00	48.00	49.00	11.33	33.00	1.27	59.67	10.36	5.10	6.40	129.90	88.67	4.50	831.37
T_8	80:60:80	49.33	49.67	49.33	11.67	34.00	1.23	59.60	10.41	5.03	6.47	130.65	87.67	5.33	844.90
T_9	80:80:0	47.33	50.00	49.33	12.00	35.33	1.25	61.50	9.79	4.77	6.28	115.54	87.67	4.00	725.95
T_{10}	80:80:60	49.67	50.67	49.67	12.00	35.33	1.40	61.17	10.62	5.23	6.62	136.22	88.33	4.33	901.35
T_{11}	80:80:80	51.00	51.00	49.67	12.33	35.67	1.25	60.83	10.89	5.13	6.63	135.49	**90.33**	6.50	898.72
T_{12}	80:80:100	50.33	51.67	50.00	13.00	37.33	1.56	61.33	9.84	**5.60**	6.87	138.33	89.00	6.50	949.85
T_{13}	80:100:60	52.00	52.00	50.00	13.00	37.33	1.24	59.83	9.09	4.83	6.95	137.25	88.00	4.33	953.86
T_{14}	80:100:100	50.33	51.00	49.67	12.67	36.00	1.07	61.00	**8.02**	5.23	7.18	125.86	88.33	6.00	904.08
T_{15}	60:100:80	48.33	47.67	49.00	11.33	32.33	1.00	59.00	8.16	4.93	6.87	120.03	89.33	5.50	824.20
T_{16}	100:80:60	52.67	52.33	50.33	13.67	39.33	1.20	59.33	8.94	5.53	6.98	140.27	89.33	4.33	979.56
T_{17}	100:80:80	53.00	52.33	50.60	13.67	40.00	1.00	**58.00**	9.42	4.80	7.30	135.13	89.67	5.67	986.47
T_{18}	100:80:100	**55.00**	52.65	**50.67**	**14.00**	40.33	**1.67**	58.67	9.36	5.03	**8.33**	119.93	89.67	6.50	999.39
T_{19}	80:60:100	50.33	51.33	50.00	12.67	37.33	1.60	58.50	9.54	5.27	6.72	129.62	89.00	6.67	870.63
T_{20}	80:100:80	52.33	52.00	50.33	13.33	39.67	1.02	58.67	8.56	5.23	6.80	**142.52**	89.50	5.67	969.15
T_{21}	100:100:100	**55.00**	**52.67**	**50.67**	**14.00**	**41.00**	1.57	58.33	9.62	5.10	8.22	122.71	90.00	**6.67**	**1008.3**
T_{22}	Control	42.33	42.00	46.00	7.00	20.33	1.00	61.83	12.13	4.30	4.80	116.49	87.67	3.50	559.15
T_{23}	5 tons FYM/ha	43.00	44.33	47.00	7.00	20.67	1.07	62.50	12.58	4.97	5.25	117.53	87.33	4.00	617.05
T_{24}	10 tons FYM/ha	42.67	45.00	47.33	8.00	24.67	1.04	62.67	11.21	5.00	5.20	123.09	87.67	3.67	640.06
	SEm (±)	1.23	2.05	1.67	0.49	1.30	0.10	1.36	1.20	0.14	0.29	0.95	0.24	0.11	4.01
	CD	3.51	5.83	NS	1.40	3.70	0.29	NS	NS	0.41	0.83	2.70	2.54	0.97	11.40

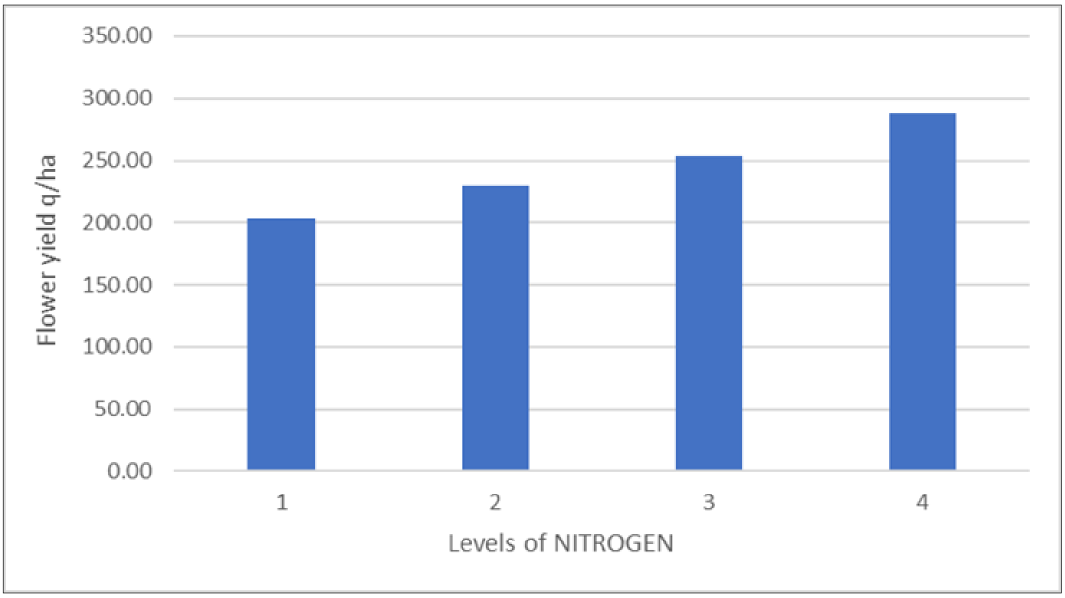

Fig. 4. Effect of graded nitrogen doses on flower yield of African marigold.

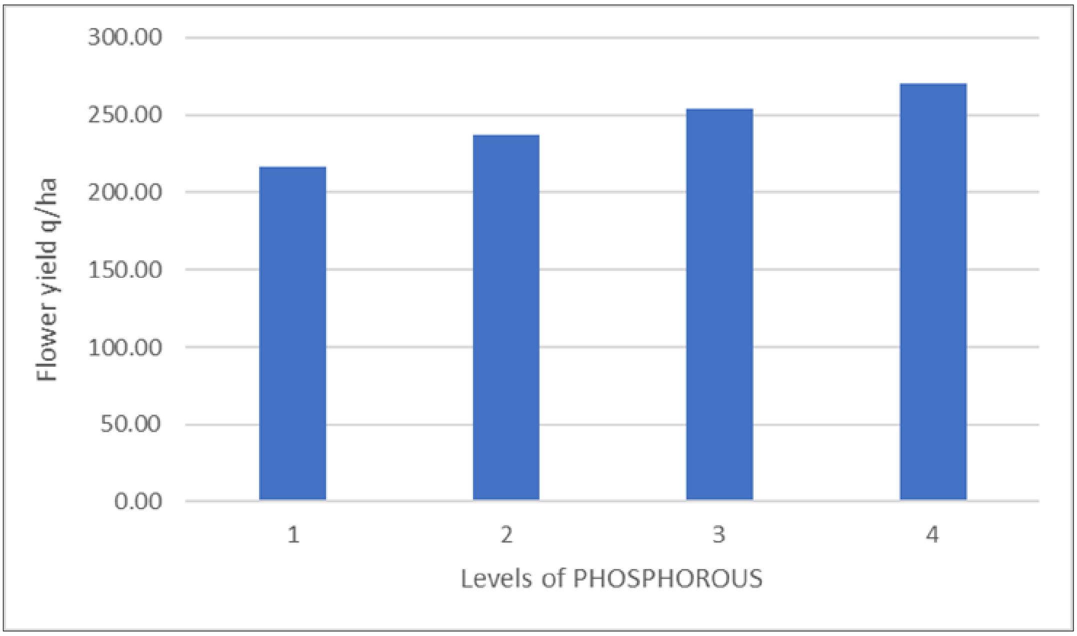

Fig. 5. Effect of graded phosphorus doses on flower yield of African marigold.

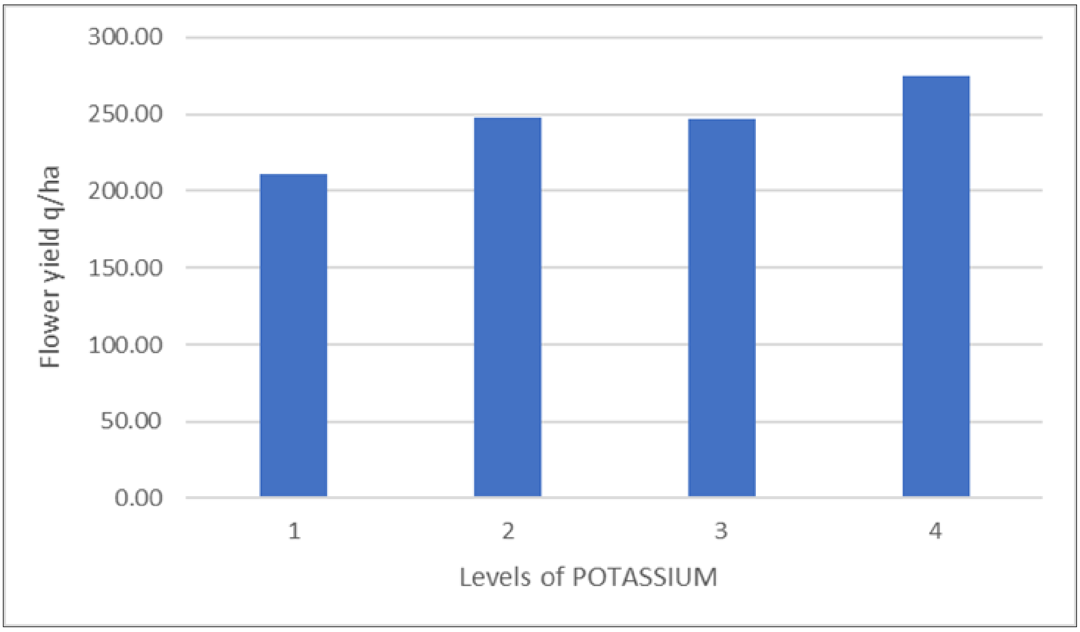

Fig. 6. Effect of graded potassium doses on flower yield of African marigold.

promotion through increased nutrient availability and the latter's natural development of a plant unfolding into its flowering phase (14, 17, 18). These findings contradict earlier research on marigold, which suggested that slightly earlier flower bud differentiation and eventual flowering initiation could have resulted from accumulated carbohydrates due to increased nutrient availability above and beyond burnt up through respiration in heavy-dosed treatments (4, 19-21). Furthermore, early flowering and balanced management of the vegetative and reproductive stages may have been facilitated by a modified C:N ratio (22).

The positive effects of NPK on flower weight and size may be attributed to phosphorus, which plays a vital role in the formation of floral initials, resulting in a greater number of flowers. Nitrogen increases protein synthesis, which in turn promotes the development of floral primordia (23). Potassium improves nutrient uptake and translocation, which keeps flowers turgid and heavy (8). These effects may be linked to plants receiving higher doses of primary nutrients, which helped them reach their maximum height, number of branches, number of leaves and larger leaf area. This, in turn, led to improved photosynthates, which formed earlier, larger and heavier blooms. According to previous studies, applying organic manures greatly increased fresh plant weight, fresh flower yield per plant and dry matter yield per plant (24). This effect may have been caused by the high nitrogen content of inorganic fertilizers (25, 26). The higher yields obtained with a higher fertilizer dose were consistent with earlier studies on marigold, which reported that higher doses of N, P and K increased flower yield (4, 19, 27, 28).

Conclusion

Marigold is one of the most significant and profitable commercial loose flower crops cultivated in open fields across India, including Odisha. They are cultivated in the decorative flower industry for a variety of purposes. Marigold serves multiple purposes, from daily household uses such as divine offerings to applications in cosmetics, textiles, pharmaceuticals and the poultry industry. The possible quality yields vary greatly between locales because of differences in soil type, fertility, climate and genotype. Reduced nutrient utilization efficiency is the result of uneven and careless fertilizer application; on the other hand, excessive fertilizer use has resulted in environmental pollution issues. Addressing the different problems associated with nutrient management in marigold requires research on balanced and sustained nutrition using traditional soil-test-dependent fertilization approaches. According to the findings of this study, NPK 100:100:100 kg/ha provided the best flower production and NPK 80:100:100 kg/ha produced the maximum number of flowers.

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Authors' contributions

SKP carried out the funding, design and coordination of the experiment. BPS and AM was responsible for drafting the manuscript, providing technical help and contributing to the study design. SB coordinated the experiment, while GRR performed the statistical analysis and assisted with the study design. DK contributed to drafting the manuscript and participated in coordinating the study and SS assisted in drafting the manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used QuillBot for paraphrasing and Turnitin for plagiarism checking. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the final content of the publication.

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