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Standardization of a Sustainable Organic Manure and Biofertilizer Packages for Growth, Yield, Flower Quality and Economics of African Marigold in the Garhwal Himalaya

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Abstract: The present investigation was carried out to elucidate the effect of different organic manures and bioinoculants on growth, yield, flower quality and economics of African marigold at Floriculture Block, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal, Uttarakhand. The experiment was laid out with twelve treatments replicated thrice in randomized complete block design. The results showed that tallest plants (86.68 cm), maximum number of primary branches (14.65), plant spread (67.89 cm) and number of leaves per plant (205.26) were recorded in treatment containing 50 % 'N' Vermicompost + 50 % 'N' Neem Cake + Biofertilizers. Similarly, minimum days taken to bud appearance and first flowering first flowering (56.26 and 70.66 days, respectively), longest flowering duration (58.86 days), flower diameter and flower weight (7.90 cm and 6.11 g, respectively), number of flowers per plant and per m^2 (46.43 and 376.11, respectively), flower yield per plant and per m^2 (285.08 g and 2.36 kg, respectively) and cost benefit ratio (1:1.57) were recorded from plants grown in plots applied with same treatment. Therefore, it can be concluded that application of 50 % 'N' Vermicompost + 50 % 'N' Neem Cake + Biofertilizers (20 mL/L) was found highly economical and effective in improving yield and quality of African marigold cv. Pusa Narangi Gainda in the Garhwal Himalya.

Keywords: FYM • Neem cake • Goat Manure • Vermicompost • *Azotobacter* • PSB and KMB

Introduction

African marigold (*Tagetes erecta* L.) is one of the most important commercial flower crops grown in India. It belongs to the family Asteraceae and native to Mexico. The flowers are used for religious and ceremonial purposes and have a high demand in festivals. It is one of the most important bedding plants and used in herbaceous borders. In addition to it, nowadays crop has gained economic importance. The crop is also utilized for carotenoid particularly lutein extraction (Chetia *et al* 2025), which is widely used as a natural colouring agent in food and textile industries and in nutraceutical formulations for eye health (Bhardwaj *et al* 2025). Additionally, marigold is used as feed supplement in poultry and aquaculture to enhance the pigmentation of egg yolk as well as the skin of broiler and fish (Sowbhagya *et al* 2006). The plant is known to produce secondary metabolites i.e. α-terthienyl and other thiophenes, which possess nematicidal, insecticidal and antifungal activities (Salehi *et al* 2018). The aesthetic and economic advantages of the crop make it highly preferred among growers. Moreover, its ease of cultivation and adaptability to diverse climatic conditions make it an ideal choice for small and marginal farmers.

Plant growth and development largely depend on proper nutrition. However, for short-term benefits, growers often apply excessive amounts of chemicals, which deteriorate soil fertility and reduce long term crop productivity (Bartwal and Bohra 2025). Dhuldhaj *et al* (2023) reported that the continuous and indiscriminate use of agrochemicals has also led to serious environment pollution affecting human health

and biodiversity. Therefore, there is a growing shift towards alternative nutrients sources such as organic manures and biofertilizers, which improve soil health, enhance microbial activity and supports long-term sustainability (Chatterjee *et al* 2025). Organic manures improve physical, chemical and biological properties of soil (Mahant *et al* 2018). FYM enhances crop yield and soil microbial population (Kumar and Chaudhary 2018), while vermicompost is nutrient rich organic manure with diverse microbial communities (Hakeem *et al* 2021). Goat manure is an excellent source of soil conditioner which improve soil texture and water holding capacity, creating a favourable environment (Singh *et al* 2024), whereas neem cake acts as a natural fertilizer with pesticidal properties (Patel *et al* 2018).

Biofertilizers are living microorganisms derived from the rhizosphere and croplands that improve soil fertility and create a favourable environment for crop growth (Yadav and Dwivedi 2025). *Azotobacter*, a free-living aerobic nitrogen-fixing bacterium, increases available nitrogen in soil through biological nitrogen fixation and help to reduce the application of nitrogen fertilizers application by about 20-25 % (Kumar 2015). Phosphate solubilizing bacteria (PSB) convert insoluble phosphorous into soluble form, enhancing root growth and nutrient uptake (Parmar *et al*., 2017). Potassium-mobilizing bacteria (KMB) improve potassium availability in soils, facilitating its uptake by plants (Patel *et al*. 2021).

Keeping in view the above aspects and popularity of crop among growers, the present investigation was conducted to study the effect of organic manures and biofertilizers on growth, yield, flower quality and economics of African marigold cv. Pusa Narangi Gainda in the Garhwal Himalaya. The findings are expected to benefit flower growers in the hill regions of Uttarakhnand as well as in similar agroecological zone across India.

Material and methods

An investigation was carried out at Research farm of the Department of Floriculture and Landscaping Department, College of Horticulture, Veer Chandra Singh Garhwali, Uttarakhand University of Horticulture and Forestry, Bharsar, District Pauri Garhwal (Uttarakhand) in summer season, 2024. Bharsar is located in the Shivalik range of the central Himalayan region between 29º 20' - 29º 75' N and 78º 10' - 78º 80' E. The sites lie at an altitude of 1900 meters above sea level. The soil of experiment field is sandy loam in texture with a pH of 6.28 and electrical conductivity (0.21 dS/m). The soil contains 1.21 % organic carbon, while the available nutrient status was 409.5 kg/ha nitrogen, 21.87 kg/ha phosphorus P_2O_5 and 45.69 kg/ha available K_2O. The experiment was laid out in Randomized Complete Block Design with three replications and fifteen. The experiment consisted of twelve treatments replicated thrice in Randomized Complete Block Design (RCBD). The treatments details are presented in Table 1

Table 1: Details of Treatment Combinations of Organic Nitrogen Sources and Bio-fertilizers

Treatment code	Treatment details
T_1	Control
T_2	100 %'N' FYM + Biofertilizers
T_3	100 % 'N' Vermicompost + Biofertilizers (20 mL/L)
T_4	100 % 'N' Goat Manure + Biofertilizers (20 mL/L)
T_5:	100 % 'N' Neem Cake + Biofertilizers (20 mL/L)
T_6	50 % 'N' FYM + 50 % 'N' Vermicompost + Biofertilizers (20 mL/L)
T_7	50 % 'N' FYM + 50 % 'N' Goat Manure + Biofertilizers (20 mL/L)
T_8	50 % 'N' FYM + 50 % 'N' Neem Cake + Biofertilizers (20 mL/L)
T_9:	50 % 'N' Vermicompost + 50 % 'N' Goat Manure + Biofertilizers (20 mL/L)
T_{10}	50 % 'N' Vermicompost + 50 % 'N' Neem Cake + Biofertilizers (20 mL/L)
T_{11}	50 % 'N' Goat Manure + 50 % 'N' Neem Cake + Biofertilizers (20 mL/L)

T_{12}	25 % 'N'FYM + 25 % 'N' Vermicompost + 25 % 'N' Goat Manure + 'N' Neem Cake + Biofertilizers (20 mL/L)

The recommended dose of fertilizers for the crop was 200:100:100 kg N: P_2O_5:K_2O /ha (Singh and Sisodiya 2014). The required nitrogen was supplied through different organic manures according to the treatment combinations. The healthy and uniform size seedlings of African marigold cv. Pusa Narangi Gainda were transplanted at a spacing of 40 cm × 30 cm, accommodating 12 plants per plot. FYM, vermicompost, goat manure and neem cake were applied uniformly as per treatment allocation and incorporated into the soil 2 weeks before transplanting of seedlings. Biofertilizers [*Azotobacter* + PSB + KMB (20 mL/L)] was applied through the seedling root-dipping method. The roots of seedlings were dipped in solution for 30 minutes per treatment before transplanting. The observation on growth, yield and flower quality was recorded at the time of full bloom. The data were analyzed according to the procedure recommended by Gomez and Gomez (1984).

Results and discussion

The data on vegetative and flowering parameters of African marigold cv. Pusa Narangi Gainda, as influenced by different sources of organic manures and biofertilizers, are presented in Table 2. The tallest plants (86.68 cm), maximum number of primary branches and leaves per plant (14.65 and 205.26, respectively), plant spread (67.89 cm) were recorded in plants grown in plots supplied with T_{10} [50 % 'N' Vermicompost + 50 % 'N' Neem Cake + Biofertilizers (20 mL/L)]. The superiority in vegetative parameters under T_{10} might be attributed to the combined application of organic manures and biofertilizers, thereby promoting increased biosysentheis and metabolic activities in plants. Vermicompost not only supplies essential nutrients such as N, P and K but also serves as a rich source of micronutrients and beneficial enzymes (Singh *et al*., 2015). Eifidiyi *et al*. (2015) reported that neem cake, upon decomposition enhances soil microbial activity and directly influences vegetative growth of plants. Parmar *et al* (2017) also stated that *Azotobacter* and PSB helps in increasing the availability of nitrogen and phosphorus to the root zone which directly improve growth and development. Similarly, KMB enhance the solubilization of potassium, increasing its availability in the soil. These findings are in agreement with reports of Arha *et al* (2021) in gaillardia, Gunda *et al* (2022) in sweet basil and Ranjan and Bohra (2023) in African marigold.

The earliness in flowering was significantly influenced by different organic manures and biofertilizers. The minimum number of days taken to first bud appearance and first flower opening (56.26 and 70.66 days, respectively) were recorded from plants grown in plots applied with 50 % 'N' Vermicompost + 50 % 'N' Neem Cake + Biofertilizers (20 mL/L) and found statistically at par with treatment T_6 (58.40 and 72.29 days, respectively). This could be due to vigorous vegetative growth registered under the same treatment that leads to earliness in flowering. The balanced supply of macro nutrients from vermicompost, neem cake and bioinoculants promotes translocation of phytohormones to the shoots resulting in earliness in flowering (Rohith *et al* 2021). Vermicompost provides humic acid and growth promoting substances (Patel *et al* 2020), while, neem cake supplies nutrients and amino acids and protect the plants from insect's attack (Arha *et al* 2021).

In addition, biofertilizers inoculation might have favoured an increased accumulation of dry matter and also efficient partitioning of photosynthates towards the sink (Ashok *et al* 2023). The above results are corroborated with the findings of Marak *et al* (2020) in China aster, Paikra *et al* (2022) in African Marigold and Bhatt and Bohra (2024) in China aster.

Table 2 : Effect of organic manures and biofertilizers on vegetative and flowering parameters of African marigold cv. Pusa Narangi Gainda

Treatments	Plant height (cm)	Number of primary branches per plant	Plant spread (cm)	Number of leaves per plant	Number of days taken for 1st bud appearance	Number of days taken for 1st flower opening	Flowering duration (days)	Flower diameter (cm)	Individual flower weight (g)
T_1	60.37	8.51	44.87	157.80	68.53	84.86	45.06	5.29	4.24
T_2	78.11	12.06	61.88	175.26	59.20	73.46	54.46	6.34	5.32
T_3	81.39	12.18	60.34	192.00	60.13	73.26	57.06	7.29	5.73
T_4	79.66	9.15	46.93	182.86	66.13	83.13	46.85	6.03	4.86
T_5	74.06	11.06	55.20	182.06	62.73	76.46	53.33	6.04	4.93
T_6	84.20	13.08	65.68	193.73	58.40	72.29	56.13	6.82	5.35
T_7	63.43	10.48	54.02	185.93	64.13	79.46	49.33	6.03	4.86
T_8	71.67	10.21	58.80	178.73	62.06	77.26	52.46	6.04	5.00
T_9	72.27	12.88	51.71	177.40	63.33	81.40	51.40	6.04	4.88
T_{10}	86.68	14.65	67.89	205.26	56.26	70.66	58.86	7.90	6.11
T_{11}	70.61	10.76	48.37	193.00	65.46	82.20	48.33	6.05	4.85
T_{12}	80.47	12.51	64.32	189.00	61.40	74.66	55.20	6.68	5.68
S.E(d)	1.23	0.68	0.86	3.77	0.81	0.82	0.85	0.34	0.27
$C.D_{0.05}$	2.58	1.42	1.81	7.86	1.69	1.72	1.77	0.71	0.56

The longest flowering duration (58.86 days) in African marigold cv. Pusa Narangi Gainda was recorded in T_{10} [50 % 'N' Vermicompost + 50 % 'N' Neem Cake + Biofertilizer (20 mL/L)]. The extended flowering duration might be due to optimum application of vermicompost and neem cake along with biofertilizers, which improve soil health, water retention capacity and microbial activity. Their incorporation also enhances soil enzyme activities such as urease, phosphomonoesterae and phosphodisterase (Ranjan and Bohra, 2023). The finding resonates with previous studies demonstrating the positive impact of application of organic manures along with biofertilizers on flowering duration also been reported by Dixit *et al* (2021) in chrysanthemum and Lakra *et al.* (2025) in African marigold. Similarly, biggest flower (7.90 cm) and maximum individual flower weight (6.11 g) were also recorded in treatment T_{10}. Biofertilizers facilitate better translocation of photo assimilates towards developing buds, resulting in increased flower diameter and weight (Arha *et al* 2021). Moreover, vermicompost and neem cake improve soil fertility by supplying nutrients and enhancing microbial activity (Eifidiyi *et al* 2015). All these factors contributed to increase in flower diameter and individual weight. Similar findings were reported by Choudhury *et al.* (2020) in African marigold and Singh *et al* (2024) in China aster.

The data presented in Table 3 showed that all the applied treatments significantly increased flower yield of African marigold cv. Pusa Narangi Gainda. The maximum numbers of flowers per plant and per m^2 (46.43 and 376.11, respectively) were obtained from the plants grown in plots applied with treatment T_{10} [50 % 'N' Vermicompost + 50 % 'N' Neem Cake + Biofertilizers (20 mL/L)]. Similarly, maximum flower yield per plant and per m^2 (285.08 g and 2.36 kg, respectively) were also recorded in the same treatment. This might be due to maximum number of primary branches per plant, number of leaves per plant and plant spread were registered under the same treatment which leads to production of more photosynthates, which would have produced more flowers. The results also showed that maximum individual flower weight was also recorded on the same treatment that could attributed to maximum flower yield per plant and per m^2. Rolaniya *et al* (2017) reported that inoculation of marigold seedlings with PSB culture significantly increased crop growth, nitrogenase activity, nutrient uptake and over all crop yield. Similarly, Verma *et al* (2023) observed that combined application of organic manures along with biofertilizers improved

nutrient uptake and translocation, activated enzymatic activities and promoted cell division and elongation that promotes flower yield in China aster. The increase in number of flowers per plant with the application of neem cake and bio fertilizers has also been recorded by Singh *et al* (2024) in China aster. Similar results were also observed by Choudhary *et al.* (2020) in marigold and Sharma *et al.* (2025) in marigold.

Table 3 Effect of organic manures and bio-fertilizers on flower yield of African marigold cv. Pusa Narangi Gaind

Treatments	Number of flowers per plant	Number of flowers per m^2	Flower yield per plant (g)	Flower yield per m^2 (kg)
T_1	30.41	277.77	129.09	1.06
T_2	34.53	335.00	184.08	1.53
T_3	36.59	358.89	209.87	1.74
T_4	36.03	282.33	156.34	1.30
T_5	36.71	332.78	181.45	1.51
T_6	36.90	352.78	202.42	1.69
T_7	34.26	285.55	158.93	1.32
T_8	38.40	320.00	192.39	1.60
T_9	37.73	314.44	178.82	1.49
T_{10}	46.43	376.11	285.08	2.36
T_{11}	34.73	289.44	156.79	1.30
T_{12}	41.73	348.33	236.98	1.97
S.E(d)	1.02	2.74	3.82	0.10
$C.D_{0.05}$	2.14	5.72	7.98	0.21

The different treatments had a significant effect on cost of cultivation of African marigold cv. Pusa Narangi Gainda (Table 4). The maximum cost of cultivation (₹ 3,41,391.00 /ha) was recorded in T_5 [100 % 'N' Neem cake Biofertilizers (20 mL/L]. However, minimum cost of cultivation was recorded in T_1 (₹ 1,35,531.00 /ha). The lowest cost of cultivation under control might be due to no application of manures and biofertilizers. The maximum gross return, net return and cost : benefit (₹ 7,09,992.00 /ha, ₹ 4,33,601.00 /ha, 1:1.57, respectively) were recorded in T_{10} [50 % 'N' Vermicompost + 50 % 'N' Neem Cake + *Azotobacter* + PSB + KMB (20 mL/L)]. This might be due to highest flower yield were registered under the same treatments. Kumar *et al.* (2009) reported that application of organic manures and bioinoculants recorded maximum cost benefit ratio in African marigold. Vermicompost is a nutritive organic fertilizer enriched with plant available forms of macro (Nitrogen, Phasphorus and Potassium) and micro (Iron, Copper, Zinc etc.) nutrients. It also contains beneficial soil microorganism, including nitrogen fixing and phosphate solubilizing bacteria, actinomycetes and plant growth regulators such as auxin, cytokinins and gibberellins (Adhikari *et al*., 2018). Eifediyi *et al*. (2015) reported that neem seed cake enrich in the nutrients, which increases the carbon content and improves soil physical properties. The above results are in close conformity with findings of Pavan *et al.* (2015) and Marak *et al.* (2020) in China aster.

Table 4 Effect of organic manures and biofertilizers on economics of African marigold cv. Pusa Narangi Gainda

Treatments	Estimated yield (kg/ha)	Flower Selling rate (₹30/kg)	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	Cost benefit ratio
T_1	10744.86	30.00	1,35,531.00	3,22,346.00	1,86,815.00	1:1.38
T_2	15318.64	30.00	1,81,391.00	4,59,559.00	2,78,168.00	1:1.53
T_3	17485.07	30.00	2,11,391.00	5,24,552.00	3,13,161.00	1:1.48
T_4	13052.07	30.00	2,91,391.00	3,91,562.00	1,00,171.00	1:0.34

T_5	15093.25	30.00	3,41,391.00	4,52,798.00	1,11,407.00	1: 0.33
T_6	16451.20	30.00	1,94,391.00	4,93,537.00	2,99,146.00	1: 1.54
T_7	13249.77	30.00	2,36,391.00	3,97,493.00	1,61,102.00	1: 0.68
T_8	16021.33	30.00	2,61,391.00	4,80,640.00	2,19,249.00	1:0.84
T_9	14904.66	30.00	2,51,391.00	4,47,140.00	1,95,749.00	1:0.78
T_{10}	23666.39	30.00	2,76,391.00	7,09,992.00	4,33,601.00	1:1.57
T_{11}	13063.59	30.00	3,16,391.00	3,91,908.00	75,516.60	1:0.24
T_{12}	19776.96	30.00	2,56,391.00	5,93,309.00	3,36,918.00	1:1.31

Conclusion

The above findings showed that application of 50 % 'N' Vermicompost + 50 % 'N' Neem Cake + Biofertilizers (20 mL/L) was found highly economical and effective in improving yield and quality of African marigold cv. Pusa Narangi Gainda in the Garhwal Himalya.

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