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RESEARCH ARTICLE

Vegetative and floral parameters of African marigold (*Tagetes erecta* L.) influenced by fertilizer, organic manure and liquid consortia under the semi-arid region of Bundelkhand, Uttar Pradesh, India

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Abstract

The field experiment was carried out to evaluate the effect of fertilizers, manures and liquid consortia on vegetative and floral characters in marigold cv. Pusa Narangi Gainda. The experiment was conducted at Research Farm, Department of Floriculture and Landscape Architecture, College of Horticulture, Banda University of Agriculture and Technology, Banda during September 2021 to January 2022. The experiment was laid out in Randomized Block Design (RBD) comprising of 10 treatments. Application of 75 % Recommended Dose of Fertilizer (RDF) + vermicompost @ 10 t/ha + liquid consortia @ 625 mL/ha was most effective in increasing the vegetative parameter such as maximum number of primary branches (25.4), maximum number of leaves per plant (258.1), maximum plant spread (41.7 cm), leaf area (45.3 cm^2). Further, the treatment also performed better for floral parameters such as first bud initiation (36.2 days), days to first flowering (45.7 days), duration of flowering (61.1 days), number of flowers per plant (34.2), flower yield per plant (0.295 kg) and flowers weight per plot (5.928 kg). Whereas maximum plant height (75.62 cm), stem diameter (12.25 mm), flower diameter (6.1 cm) and flower weight (l.177 g) were recorded in the treatment applied with 75 % RDF + Farmyard Manure (FYM) @ 20 t/ha + liquid consortia 625 mL/ha.

Keywords: African marigold; farmyard manure; liquid consortia; vermicompost; yield

Introduction

Marigold (*Tagetes erecta* L.) is one of the most popular and commercially cultivated ornamental flower crops in India. It belongs to the family Asteraceae and native to South and Central America, including Mexico. Marigold is a versatile crop and grown commercially in different parts of the country for loose flower production. Marigold holds significant position in ornamental horticulture as it has a wide adaptability to various soil and climatic conditions. It also serves as an important commercial source of carotenoid; a natural pigment mostly composed of esters of xanthophylls (lutein) and is being used commercially to enhance yolk coloration and broiler skin (1). Marigold exhibits several therapeutic properties, including antioxidant, antimicrobial and anti-inflammatory activities (2). Besides, marigold is being used for the extraction of oleoresin, a natural colorant and nutraceutical compound with significant applications in the food and pharmaceutical industries, particularly in the management of retinal disorders (3).

Marigold responds as well to nutrition (4). The excessive and unbalanced use of chemical fertilizers, particularly nitrogen (N), phosphorus (P) and potassium (K), in modern agriculture has caused several environmental and soil-related problems. High nitrogen use can result in nitrate leaching, water pollution (eutrophication) and greenhouse gas emissions such as nitrous oxide (5). Overuse of phosphorus contributes to freshwater contamination and soil accumulation, reducing its availability to plants. Improper potassium levels can harm soil structure and reduce water use efficiency in crops (6). Moreover, the long-term dependence on chemical fertilizers tends to the degrade soil structure and fertility, making crops increasingly dependent on external inputs (7,8). Besides, it also lowers the microbial diversity and activity, which are essential for nutrient cycling and soil health. Application of Integrated Nutrient Management (INM) that combines organic manures, biofertilizers and balanced chemical fertilizers, is crucial for improving nutrient efficiency, sustaining soil health and maintaining the economic yield and profitability. The combined application of biofertilizers and fertilizers may be useful in the increased production of quality flowers (9,10). Organic manures, particularly FYM and vermicompost, are fundamental components of INM and are widely adopted by farmers to sustain and improve soil fertility. Vermicompost contributes to the enhancement of soil structure, surface roughness and water retention capacity, improving the physicochemical properties of soil and significantly stimulate microbial activity thereby improving plant nutrition and promoting overall plant growth (11). FYM support plant nutrition by providing essential macronutrients, including nitrogen (0.5–1.0 %), phosphorus (P_2O_5: 0.4–0.8 %) and potassium (K_2O: 0.5–1.9 %) and also improves soil aggregation and structure (12). Optimizing conditions for microbial processes ensures improved nutrient availability, leading to enhanced plant development (13). In recent years, biofertilizers have emerged as effective supplements within INM strategies. Soil microbial activity has been reported to key determinants of both the quantity and quality of marigold (*Tagetes erecta* L.) production (14). Among them, liquid consortia - a formulation comprising beneficial microorganisms such as nitrogen-fixing, phosphate - solubilizing and potassium-mobilizing bacteria has shown promising results in enhancing soil health, improving both physical and chemical soil properties, increasing crop yield and suppressing plant pathogens. The liquid formulation offers the added advantage of promoting rapid and efficient rhizosphere colonization by facilitating quicker establishment of beneficial microbes near the root zone (15). Considering the above discussion the present study was under taken with an objective to select the most suitable treatment combination of liquid consortia along with organic manures and chemical fertilizer on vegetative and floral parameters of African marigold (*T. erecta* L.) cv. Pusa Narangi Gainda.

Materials and Methods

Experimental site and climate

The experiment was carried out during September 2021 to January 2022 at the Research Farm, Department of Floriculture and Landscape Architecture, College of Horticulture, Banda University of Agriculture and Technology, Banda, Uttar Pradesh, India. The experimental site is situated at an elevation of 123 m above mean sea level, between 24°53′–25°55′ N latitude and 80°07′–81°34′ E longitude. The region experiences extreme temperatures, with summer maxima reaching up to 49 °C and winter minima dropping to 7 °C. The average annual rainfall ranges from 800–910 mm, over 80 % of which is received between the third week of June and the first week of September. Rainfall during the October to January period is minimal (Fig. 1).

Experimental design and treatments

The experiment was laid out in a RBD comprising 10 treatments with 3 replications. The treatments were formulated to evaluate the performance of various combinations of chemical fertilizers, organic manures and liquid consortia on marigold (*T. erecta* L.) with the objective of assessing their impact on growth, yield and soil health, reducing the dependency on chemical fertilizers while enhancing crop performance and soil sustainability. The treatment details are as follows:

T_1: 100 % RDF - NPK @ 120:80:80 kg/ha (control)

T_2: 100 % RDF + FYM @ 20 t/ha

T_3: 100 % RDF + FYM @ 10 t/ha

T_4: 100 % RDF + Vermicompost @ 10 t/ha

T_5: 100 % RDF + Vermicompost @ 5 t/ha

T_6: 75 % RDF + Liquid consortia @ 625 mL/ha

T_7: 75 % RDF + FYM @ 20 t/ha + Liquid consortia @ 625 mL/ha

T_8: 75 % RDF + FYM @ 10 t/ha + Liquid consortia @ 625 mL/ha

T_9: 75 % RDF + Vermicompost @ 10 t/ha + Liquid consortia @ 625 mL/ha

T_{10}:75 % RDF + Vermicompost @ 5 t/ha + Liquid consortia @ 625 mL/ha

Field preparation

The experimental field was prepared to a fine tilth by 2–3 times ploughing and finally the field was levelled by planking after removing the plant residues and weeds. The beds of the required dimension were then made according to the lay out plan.

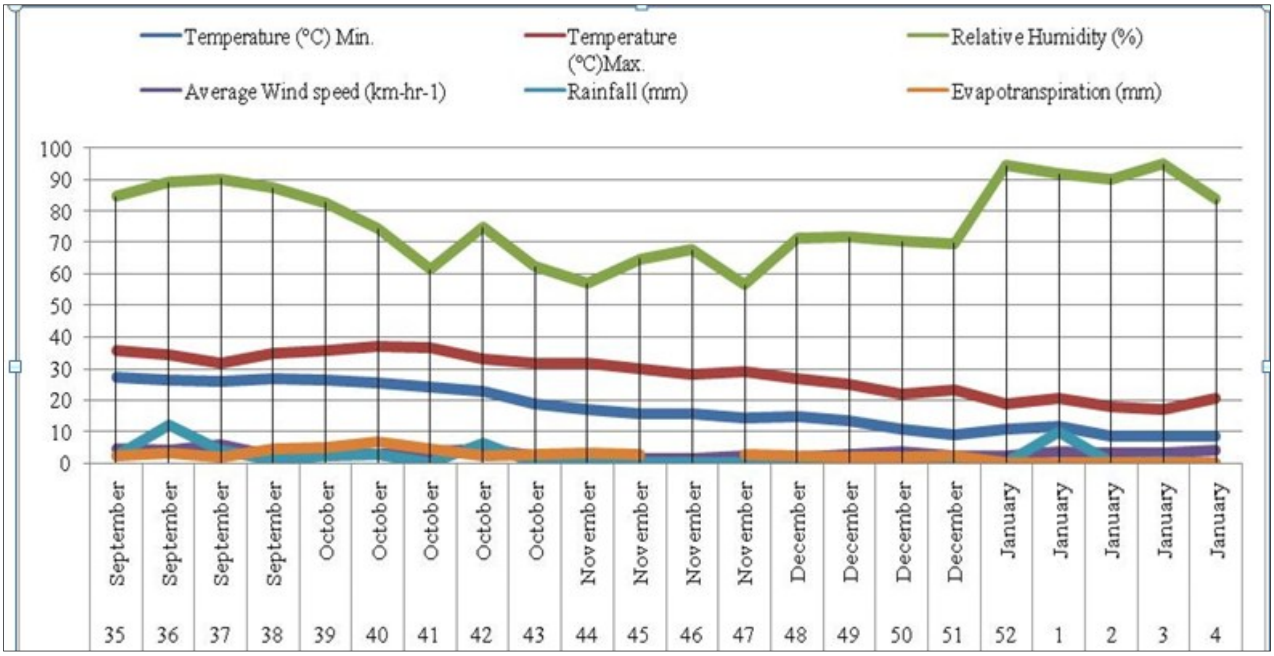

Fig. 1. Weekly meteorological observations recorded during the period of experiment at Agrometeorological Laboratory, BUAT, Banda, Uttar Pradesh.

Liquid consortia

A liquid consortium is a combination of biofertilizers developed by the Indian Farmers Fertiliser Cooperative Limited (IFFCO) to enhance soil fertility and promote sustainable agriculture. It comprises of a consortium of beneficial microorganisms that facilitate the availability of essential nutrients Nitrogen (N), Phosphorus (P) and Potassium (K).

Key components of liquid consortia

- Rhizobium (*Rhizobium leguminosarum*): Fixes atmospheric nitrogen, particularly beneficial for leguminous crops.
- Azotobacter (*Azotobacter chroococcum*) and acetobacter: Free-living nitrogen-fixing bacteria that enhance nitrogen availability in the soil.
- Phospho-bacteria (*Pseudomonas fluorescens*): Solubilize insoluble phosphates, making phosphorus accessible to plants.
- Potassium solubilizing bacteria (*Bacillus* sp.): Mobilize potassium from soil minerals, aiding in its uptake by plants.

Raising of seedlings

The seeds of African marigold cultivar Pusa Narangi Gainda were sown on a raised bed prepared 15 cm above ground level to ensure proper drainage of excess water. A bed of 2.0 m × 1.2 m was formed after thorough hoeing and weeding. Well-decomposed FYM was incorporated into the nursery bed prior to sowing marigold seeds, enhancing soil structure and microbial activity to support germination and early seedling growth.

Transplanting

Following the field preparation, the layout was executed according to the experimental plan. Healthy seedlings were transplanted in month of September 2021 in experimental plot at a spacing of 40 cm × 30 cm, accommodating 20 seedlings per bed measuring 2.0 m × 1.2 m. The seedlings were transplanted during evening to minimize transplanting shock. Light irrigation was applied immediately after transplanting to ensure proper establishment.

Estimation of available potassium and phosphorus (before transplanting)

The soil of the experimental site was analysed for the available potassium and phosphorus (Table 1). Available potassium and phosphorus were extracted with neutral normal ammonium acetate solution described by the neutral normal ammonium acetate method (16).

Statistical analysis

All the data collected on different parameters were analyzed following the Analysis of Variance (ANOVA) technique using OPSTAT software and results were evaluated using the Least Significant Difference (LSD) test at 5 % and 1 % probability levels to compare treatment means.

Results and Discussion

Vegetative parameters

The perusal of data appended in Table 2 and illustrated in Fig. 2, revealed that the plant height (75.62 cm) and stem diameter (12.25 mm) were recorded maximum in the treatment 75 % RDF + FYM @ 20 t/ha + Liquid consortia @ 625 mL/ha. This was followed by treatments 75 % RDF + Vermicompost @ 10 t/ha + Liquid consortia @ 625 mL/ha, 75 % RDF + FYM @ 10 t/ha + Liquid consortia @ 625 mL/ha and 75 % RDF + Liquid consortia @ 625 mL/ha. The increased plant height may be attributed to nitrogen, a vital component of proteins, which plays a key role in cell division and enlargement, thereby enhancing overall plant growth (17). Liquid consortia, which consist of *Rhizobium*, *Azotobacter*, *Azospirillum* and phosphorus solubilizing biofertilizers, are known to produce growth-promoting substances such as IAA and gibberellins. When applied alongside balanced chemical fertilizers, they enhance soil fertility and stimulate plant growth and development (18). Additionally, FYM improves fertilizer use efficiency and enriches the microbial quality of the soil. The combined application of these components might have resulted in the significant increase in plant height. Similar findings have been reported in marigold (19), and in China aster (20) and soybean (21).

Treatment 75 % RDF + Vermicompost @ 10 t/ha + Liquid consortia @ 625 mL/ha recorded the highest values for number of primary branches (25.4), number of leaves per plant (258.1), plant spread (41.7 cm) and leaf area (45.32 cm^2). It was significantly superior to 75 % RDF + FYM @ 20 t/ha + Liquid consortia @ 625 mL/ha, 75 % RDF + Vermicompost @ 5 t/ha + Liquid consortia @ 625 mL/ha and 75 % RDF + FYM @ 10 t/ha + Liquid consortia @ 625 mL/ha. The improved vegetative growth may be due to the synergistic

Table 1. Soil sample analysis of the experimental site before transplanting

Stage of soil sample collection	Phosphorus (Kg/ha)	Potash (Kg/ha)	Organic carbon	pH	Electrical conductivity (S/m)
Before transplanting	38.08	235.2	0.17	8.27	1.805

Table 2. Effect of chemical fertilizers, organic manure and liquid consortia on vegetative parameters of African marigold (*T. erecta* L.)

Treatment	Plant height (cm)	Number of primary branches	Number of leaves per plant	Stem diameter (mm)	Plant spread (cm)	Leaf area (cm^2)
T_1	66.32	21.27	185.87	10.94	34.96	37.13
T_2	67.60	22.53	239.47	10.10	39.08	41.77
T_3	69.97	21.67	225.67	11.71	35.96	40.21
T_4	70.92	22.4	246.6	10.23	39.74	42.27
T_5	71.5	22.06	229.13	11.46	37.34	42.59
T_6	71.67	21.73	212.13	10.92	36.4	39.62
T_7	75.62	23	251.6	12.25	41.3	44.57
T_8	72.24	22.67	244.5	10.31	39.83	44.49
T_9	72.51	25.4	258.1	11.27	41.7	45.32
T_{10}	71.30	22.87	244.73	10.89	40.1	44.57
S.E (m)±	1.40	0.27	5.01	0.497	0.45	0.97
CD @ 5 %	1.408	0.802	15.011	N/A	1.35	2.90
CV (%)	1.148	2.055	3.715	7.825	2.02	3.97

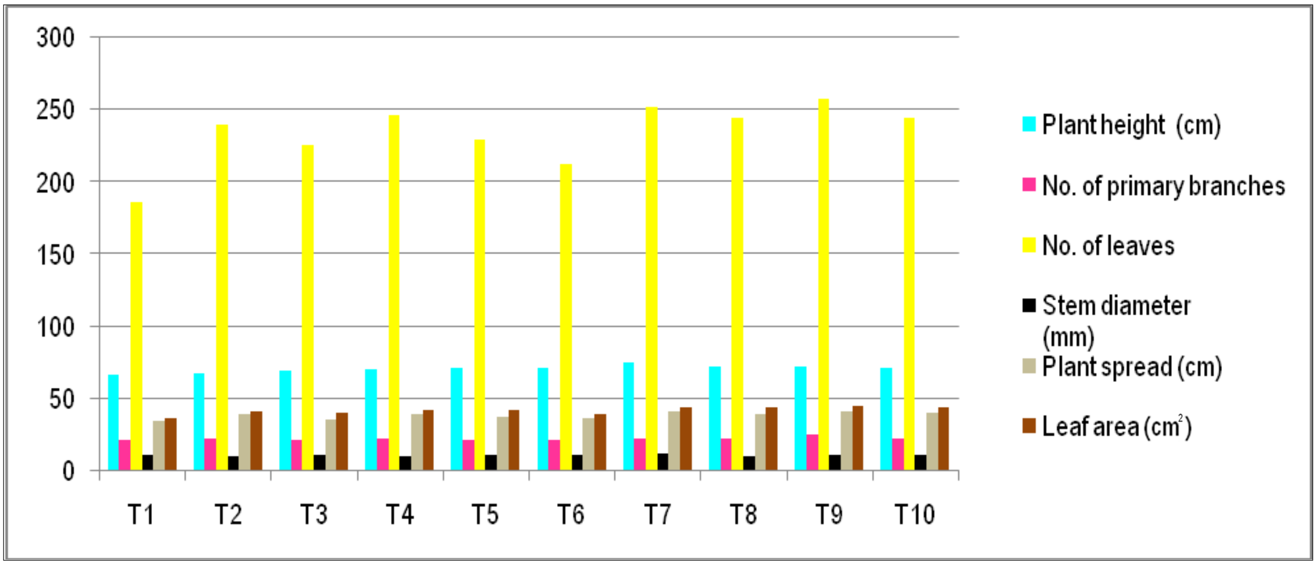

Fig. 2. Effect of chemical fertilizers, organic manure and liquid consortia on vegetative parameters of African marigold (*T. erecta* L.).

effects of chemical fertilizers, vermicompost and liquid consortia. The application of nitrogen from multiple sources has likely enhanced cell division, protein synthesis and metabolite transport, thereby stimulating vegetative growth. Vermicompost is also rich in plant growth hormones such as auxins, cytokinins and gibberellins, which contribute to enhanced plant development (22). These findings are consistent with the studies conducted in Italian aster (23) and (13,17,24) in marigold.

Flowering parameters

The data presented in Table 3 and Fig. 3, revealed earliest flower bud initiation (36.2 days) and minimum days to first flowering (45.7 days) in treatment 75 % RDF + Vermicompost @ 10 t/ha + Liquid consortia @ 625 mL/ha. This was followed by and statistically at par with treatments 75 % RDF + FYM @ 20 t/ha + Liquid consortia @ 625 mL/ha (36.3 days), 75 % RDF + Vermicompost @ 5 t/ha + Liquid consortia @ 625 mL/ha (36.4 days) and 100 % RDF + Vermicompost @ 5 t/ha (36.5). In contrast, the maximum days to flower bud initiation (38.2 days) and first flowering (45.7) were observed in 75 % RDF + vermicompost @ 10 t/ha + Liquid consortia @ 625 mL/ha. The earlier bud initiation and flowering in these treatments may be attributed to the optimal nutrient availability from the combined application of chemical fertilizers, organic manures and liquid consortia. These inputs might have promoted timely completion of vegetative growth and transition to the reproductive phase (25) and encouraging earlier flowering (26). Furthermore, the growth-promoting substances such as auxins, gibberellins, cytokinins and vitamins produced by liquid consortia might have helped in breaking apical dominance, leading to earlier flowering (19). These findings align with the results reported earlier in marigold (27).

The duration of flowering ranged from 58.27–61.13 days across treatments. The treatment 75 % RDF + Vermicompost @ 10 t/ha + Liquid consortia @ 625 mL/ha exhibited the longest flowering duration and was statistically at par with 75 % RDF + FYM @ 20 t/ha + Liquid consortia @ 625 mL/ha (61.1 days), 75 % RDF + Vermicompost @ 5 t/ha + Liquid consortia @ 625 mL/ha (60.4) and 100 % RDF + Vermicompost @ 5 t/ha (60.53 days). The extended flowering duration might be due to the synergistic effects of vermicompost and liquid consortia, which not only improve nutrient uptake but also enhance photosynthetic activity and dry matter accumulation (19,26). These findings are consistent with the results of the work conducted earlier in gladiolus (28).

The maximum flower diameter (6.17 cm) was recorded in 75% RDF + FYM @ 20 t/ha + Liquid consortia @ 625 mL/ha and was statistically at par with treatments 75 % RDF + Vermicompost @ 10 t/ha + Liquid consortia @ 625 mL/ha (6.1 cm), 75 % RDF + FYM @ 10 t/ha + Liquid consortia @ 625 mL/ha (5.9), 75 % RDF + Vermicompost @ 5 t/ha + Liquid consortia (5.61 cm). The minimum flower diameter (5.1 cm) was observed in control (100 % RDF). The increase in flower diameter is the result of combined application of these inputs that created favourable nutritional and physiological environment for the marigold plant. Liquid consortia, containing beneficial microbes

Table 3. Effect of chemical fertilizers, organic manure and liquid consortia on floral parameters of African marigold (*T. erecta* L.)

Treatments	Days to first flower bud initiation	Day to first flowering	Duration of flowering (days)	Flower diameter (cm)	Number of flowers per plant	Flower weight (g)	Flower yield per plant (kg)	Flower yield per plot (g)
T_1	38.20	51.80	58.53	5.08	27.67	4.55	0.178	3.561
T_2	36.80	48.87	60.20	5.50	31.53	5.25	0.240	4.141
T_3	37.50	50.33	60.07	5.31	30.67	5.07	0.221	4.759
T_4	36.50	48.87	60.47	5.93	32.60	5.33	0.234	4.548
T_5	37.30	49.87	60.53	5.61	31.00	5.13	0.202	4.315
T_6	37.80	49.47	58.26	5.56	29.47	5.05	0.254	5.121
T_7	36.30	47.10	61.10	6.17	32.80	6.75	0.268	5.351
T_8	37.20	47.47	61.00	5.96	32.37	6.17	0.255	5.051
T_9	36.20	45.70	61.13	6.11	34.17	6.39	0.295	5.928
T_{10}	36.40	47.73	60.40	5.93	33.67	6.23	0.254	5.087
S.E(m) ±	0.27	0.45	0.38	0.22	0.42	0.17	0.013	0.296
CD @ 5%	0.80	1.36	1.14	0.69	1.27	0.50	0.038	0.887
CV (%)	1.26	1.61	1.1	6.94	2.32	5.23	9.19	10.72

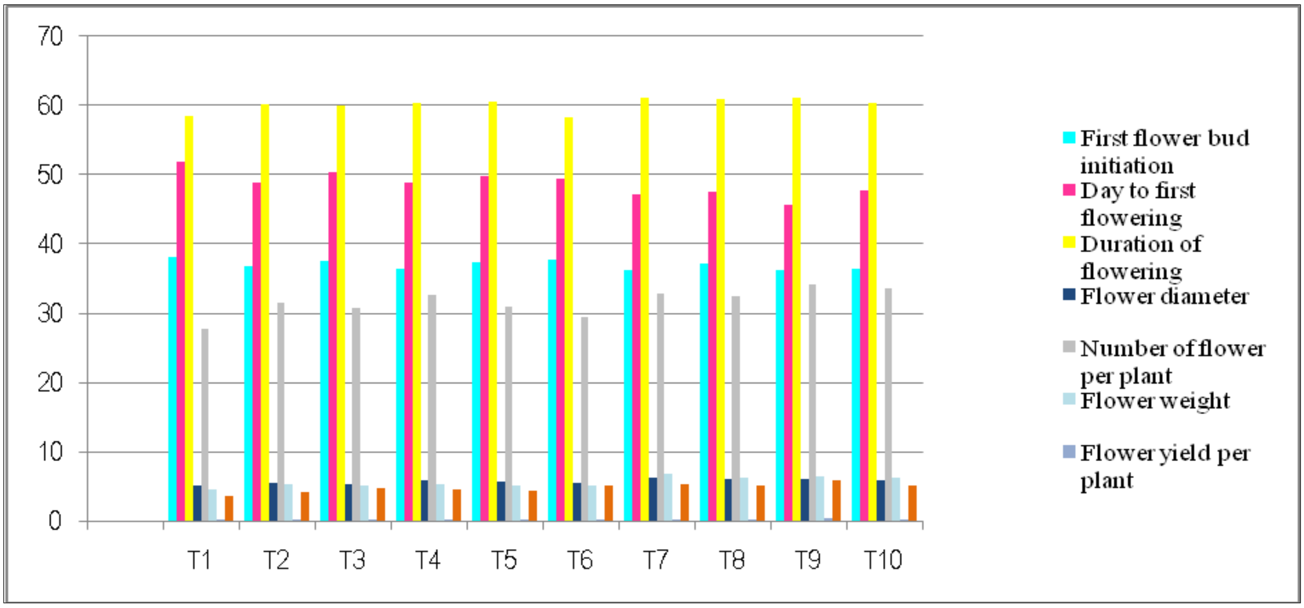

Fig. 3. Effect of chemical fertilizers, organic manures and liquid consortia practices on floral parameters of African marigold (*T. erecta* L.).

such as *Rhizobium* (*Rhizobium leguminosarum*), *Azotobacter* (*Azotobacter chroococcum*), *Azospirillum* (*Azospirillum brasilense*) and phosphorus-solubilizing bacteria, secrete organic acids that help convert insoluble phosphates into forms available to plants, contributing to improved flower development. These findings align with the results reported in marigold (18,29) and in *Gaillardia* (30).

Application of 75 % RDF + Vermicompost @ 10 t/ha + Liquid consortia @ 625 mL/ha produced the highest number of flowers per plant (34.17) and flower yield per plant (0.295 kg) and maximum flower yield per plot (5.928 kg) followed by 75 % RDF + Vermicompost @ 5 t/ha + Liquid consortia @ 625 mL/ha (33.67), 75 % RDF + FYM @ 20 t/ha + Liquid consortia @ 625 mL/ha (32.8) and 100 % RDF + Vermicompost @ 10 t/ha (32.6). The control (100 % RDF) produced the lowest number of flowers (27.68) and flower yield per plant (0.178 kg). The increased flower production is likely due to enhanced nutrient availability, stimulated hormonal and metabolic processes and better vegetative growth, which provides additional sites for flower development (22,31). These results confirm that the synergistic use of chemical fertilizers, organic manures and liquid consortia not only supports early flowering but also improves overall flower production (19, 25, 27).

Conclusion

Among the various treatments, application of 75 % RDF + Vermicompost @ 10 t/ha + Liquid consortia @ 625 mL/ha consistently outperformed others by promoting greater plant height, branching, leaf development and maximum yield of marigold flowers. In addition to this, treatment combination of 75 % RDF + FYM @ 20 t/ha + Liquid consortia @ 625 mL/ha also showed notable improvements in plant growth and flower quality. These results suggest that integrating 75 % RDF with organic amendments and biofertilizers is an effective, sustainable strategy for maximizing marigold growth and productivity.

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Authors' contributions

AK[1] carried out the experiment and wrote initial draft of the manuscript. AK[2] is involved in conceptualization, planning and supervision of experiments. AKS carried out review and editing work. RK carried out interpretation of findings. KA collected literature and summarized relevant studies. SPR carried out data recording and interpretation of the findings. KV carried out data recording and analysis. All authors read and approved the final manuscript.

[AK[1] stands for Ajay Kumar and AK[2] stands for Amit Kanawjia].

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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