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Effect of integrated nutrient management on vegetative growth and flowering of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda

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Abstract
During the winter seasons of 2020-21 and 2021-22, a field experiment was conducted on the "Effect of integrated nutrient management on vegetative growth and flowering of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda". Three biofertilizers (*Azotobacter*, *Azospirillum* and PSB) were used in the treatments, as well as three levels of vermicompost (2.0, 3.0 and 4.0 t ha^{-1}) and three levels of NPK (75, 60 and 45 percent of RDF). When compared to control, application of 60% RDF + 3 tonne/ha Vermicompost + Azotobacter + Azospirillium + PSB (T_8) resulted in maximum plant height, number of primary branches per plant, length of primary branches (cm), number of secondary branches, plant spread (cm) in (North-South) and (East-West) direction, number of leaves, fresh weight of plant (g) and dry weight of plant (g). When compared to control, the application of 45% RDF + 4 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB (T_{11}) recorded a minimum number of days to bud initiation, days to open first flower, number of days taken for 50% flowering and maximum flowering duration.

Keywords: African marigold, *Azotobacter*, *Azospirillum*, PSB, Vermicompost, flower and vegetative growth etc.

Introduction
Marigold (*Tagetes* sp. L.) is a widely used commercial flower in India. It is a member of the Asteraceae family and is native to Central and South America, particularly Mexico. *T. erecta* L. (African marigold), *T. patula* L. (French marigold), *T. sarmentosa* (climbing marigold), and *T. tenuifolia* are most significant member of the genus *Tagetes* (Rydberg, 1945) [15]. African marigold (*T. erecta* L.) is an erect, fast-growing plant with a great number of cultivable variants. Plant heights vary between 25 to 90 cm or maybe more. Deep orange, light orange, golden yellow and lemon yellow are the colours of the flowers of these cultivars. Flower sizes range from 5 to 12 cm diameter (Arora, 1989) [1] and (Singh and Sisodia, 2017) [17]. The carotenoid pigment of marigold is used in chicken feed to enhance the yellow color of egg yolks and broiler skin. On the worldwide market, natural marigold colours are in high demand. "Tagetes oil" is the aromatic oil collected from the marigold plant. It's utilized in the production of high-end perfumes as well as an insect repellant. It is also utilized as a feed supplement for the poultry sector and as a mosquitoes and nematode repellant (Bose and Yadav, 1993) [3].
Several factors influence marigold commercial cultivation including climate, soil and irrigation, fertilizer and growth season. Nutrition has a significant impact on flower growth, yield, and quality, among other factors. Micronutrient deficiency, nutritional imbalance, soil health deterioration, and decreased crop production all occurred from over use of inorganic fertilizers to achieve the maximum output. There is no single nutrition source that can provide sufficient quantities and balances of plant nutrients. As a result, integrated nutrient management is a technique that encourages the sensible and effective use of chemical fertilizers in combination with organic manures and bio fertilizers. Biofertilizers is a compound that incorporates living microorganisms those colonies the rhizosphere or the inside of the plant and promote growth by boosting the supply or availability of primary nutrients to the host plant when applied to seed, plant surfaces, or soil (Vessey, 2003) [21].
The word "bio-fertilizer" was meant to describe soil microorganisms that fixed nitrogen, mobilize plant nutrients, or conserve them. The term "bio-fertilizers" or "microbial inoculants".

refers to preparations containing microorganism strains that can aid in microbiological processes such as nitrogen fixation, phosphate solubilization or mineralization, extraction of plant growth promoting substances, or cellulose or lignin biodegradation in soil, compost, or other environments (Gaur, 2010) [5]. *Azotobacters* as well as PSB are free-living bacteria which participate in fixing atmospheric nitrogen and phosphorous solubilization in soil. *Azospirillum* is a non-symbiotic bio-fertilizer that fixes atmospheric N_2, whereas Phosphate Solubilizing Bacteria (PSB) is responsible for enhancing the availability of fixed phosphorus. Nitrogen is an essential metabolic nutrient for plant growth and development. It is mostly thought of as metabolic activities, or the conversion of energy, which are required for the metabolism of protein and other biochemical products like as nucleic acid, chlorophyll, and protoplasm. Phosphorus is a constituent of protoplasm and chlorophyll that facilitates photosynthesis to be converted into phospholipids, resulting in enough plant vegetative growth. Phosphorus is also involved in energy conversion and a variety of metabolic activities in plants. It aids in the primary photosynthesis reactions. Potassium boosts plant resilience to drought, heat, frost, and a variety of fungal and worm diseases. It also enhances the colour and aroma of the flowers, as well as their size and weight (Tisdale *et al*., 1995, Sunitha *et al*., 2007 and Luthra *et al*., 1983) [20, 18, 10].

Materials and Methods

During the winter seasons of 2020-21 and 2021-22, the present investigation was initiated at the Department of Horticulture, Research Farm-1, Babasaheb Bhimrao Ambedkar University, Vidya-Vihar, Rae-Bareli Road, Lucknow-226025. The present investigation used a Randomized Block Design with three replications and 11 different treatment combinations of biofertilizers and nutrient to study the influence on African marigold growth and flower yield. In December, thirty-day-old seedling of the African marigold variety Pusa Narangi Gainda was transplanted at 45×45cm spacing in a well-prepared seedbed of 1.8 m x 1.8 m. According to the treatment combinations, the full amount of phosphorus, potash, and vermicompost was applied soon before seedling transplantation. The roots of the seedlings were dipped in a solution of bio-fertilizers (*Azospirillum*, *Azotobactor*, and PSB) for 30 minutes @ 5 ml/lit water. The present experiment comprised with 11 treatments i.e. T_1 (Control), T_2 (100% RDF), T_3 (75% RDF + 2 t ha^{-1} Vermicompost + *Azotobacter* + PSB), T_4 (75% RDF + 2 t ha^{-1} Vermicompost + *Azospirillium* + PSB), T_5 (75% RDF + 2 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB), T_6 (60% RDF + 3 t ha^{-1} Vermicompost + *Azotobacter* + PSB), T_7 (60% RDF + 3 t ha^{-1} Vermicompost + *Azospirillium* + PSB), T_8 (60% RDF + 3 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB), T_9 (45% RDF + 4 t ha^{-1} Vermicompost + *Azotobacter* + PSB), T_{10} (45% RDF + 4 t ha^{-1} Vermicompost + *Azospirillium* + PSB) and T_{11} (45% RDF + 4 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB) these treatments were replicated thrice in Randomized Block Design (RBD). For the purposes of understanding, two years' value of data were merged and statistically examined. The observations were recorded on various parameters like plant height (cm), number of primary branches per plant, length of primary branches (cm), number of secondary branches, plant spread (cm), number of leaves, fresh weight of plant (g), dry weight of plant (g), days to bud initiation, number of days taken to open first flower, number of days taken for 50% flowering and duration of flowering (days). The statistical analysis was carried out by procedure suggested by Panse and Sukhatme (1985) [11].

Table 1: Effect of INM on vegetative growth parameters of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda

Treatment	Plant height (cm)	No. of primary branch per plant	Length of primary branch (cm)	Number of secondary branch per plant	Plant spread (cm) (North-South)	Plant spread (cm) (East-West)	Number of leaves per plant	Fresh weight of plant (g)	Dry weight of plant (g)
T_1 (Control)	88.11	16.12	25.58	17.63	68.13	69.52	168.15	327.50	75.44
T_2 (100% RDF)	103.8	22.15	49.72	26.36	75.05	76.93	222.12	388.10	89.16
T_3 (75% RDF + 2 t ha^{-1} Vermicompost + *Azotobacter* + PSB)	106.1	24.24	54.56	28.84	79.32	79.23	259.83	391.20	91.81
T_4 (75% RDF + 2 t ha^{-1} Vermicompost + *Azospirillium* + PSB)	105.0	23.32	51.65	27.88	76.21	77.89	238.00	389.80	89.83
T_5 (75% RDF + 2 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB)	108.8	26.06	57.48	29.76	81.98	81.14	278.89	414.10	93.68
T_6 (60% RDF + 3 t ha^{-1} Vermicompost + *Azotobacter* + PSB)	96.7	21.02	38.68	22.82	72.02	73.93	193.27	352.30	81.96
T_7 (60% RDF + 3 t ha^{-1} Vermicompost + *Azospirillium* + PSB)	103.5	21.78	47.86	25.04	74.42	75.75	212.98	386.75	88.05
T_8 (60% RDF + 3 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB)	115.1	26.39	58.91	32.04	83.08	82.83	286.28	421.80	95.62
T_9 (45% RDF + 4 t ha^{-1} Vermicompost + *Azotobacter* + PSB)	95.7	18.67	34.08	21.11	71.35	72.96	189.19	347.90	80.84
T_{10} (45% RDF + 4 t ha^{-1} Vermicompost + *Azospirillium* + PSB)	94.6	17.80	28.50	19.57	70.10	72.77	181.51	343.50	78.88
T_{11} (45% RDF + 4 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB)	99.1	21.51	44.95	24.17	72.93	74.77	200.31	386.40	86.02
CD at 5%	12.27	2.61	1.65	3.01	6.14	1.25	27.34	45.31	10.38
SE(m)±	4.54	0.96	0.52	3.01	1.76	0.42	10.12	16.77	3.84

Table 2: Effect of integrated nutrient management on flowering parameters of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda

Treatment	Days to bud initiation	Number of days taken to open first flower	Number of days taken for 50% flower	Duration of flowering (Days)
T_1 (Control)	57.91	72.33	76.43	42.60
T_2 (100% RDF)	53.54	59.86	66.23	53.34
T_3 (75% RDF + 2 t ha^{-1} Vermicompost + *Azotobacter* + PSB)	52.73	58.46	63.78	56.76
T_4 (75% RDF + 2 t ha^{-1} Vermicompost + *Azospirillium* + PSB)	53.30	58.81	64.78	53.93
T_5 (75% RDF + 2 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB)	54.00	62.57	68.33	49.00
T_6 (60% RDF + 3 t ha^{-1} Vermicompost + *Azotobacter* + PSB)	54.50	63.76	74.37	46.40
T_7 (60% RDF + 3 t ha^{-1} Vermicompost + *Azospirillium* + PSB)	53.86	61.92	66.87	52.80
T_8 (60% RDF + 3 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB)	52.40	54.70	61.05	57.40
T_9 (45% RDF + 4 t ha^{-1} Vermicompost + *Azotobacter* + PSB)	54.73	66.95	74.67	44.95
T_{10} (45% RDF + 4 t ha^{-1} Vermicompost + *Azospirillium* + PSB)	55.25	67.84	75.32	44.00
T_{11} (45% RDF + 4 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB)	51.40	52.68	59.12	62.33
CD at 5%	1.51	7.57	8.35	6.45
SE(m)±	0.42	2.80	3.09	2.39

Results and Discussion

Growth parameters

Statistical analysis of the data (Table-1) showed that the different permutations of bio-fertilizers and integrated nutrient management affected the vegetative growth parameters significantly throughout both years of the investigation. An examination of the data shows that the maximum plant height (115.1 cm), number of primary branches per plant (26.39), length of primary branches (58.91cm), number of secondary branches (32.04), plant spread (cm) at (North-South) direction (83.08cm), plant spread (cm) at (East-West) direction (82.83cm), number of leaves (286.28), fresh weight of plant (g) (421.80g) and dry weight of plant (g) (95.62g) were observed under the application of T_8 and it was revealed to be significantly higher to all other treatments, followed by T_5 treatment. The minimum plant height, number of primary branches per plant, length of primary branches, number of secondary branches, plant spread (cm) at (North-South) and (East-West) direction, number of leaves, fresh weight of plant and dry weight of plant of marigold was noticed in T_1 (Control) during both the years 2020-21 and 2021-22 as well as in pooled mean basis. Results clearly show that the combined application of 60% RDF + 3 ton ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB (T_8) in comparison to other treatments, it found to be beneficial for plants growth. That might be because nitrogen, phosphorus and potash fertilizer application in combined effect with bio-inoculants (*Azotobactor, Azospirillum*, and PSB) and vermicompost has been shown to be advantageous in fixing atmospheric nitrogen and solubilizing fixed phosphorus in soil, as well as secreting compounds such as auxin, which encourage plant metabolic reactions and photosynthetic effectiveness, resulting in improved plant growth and development. Further, *Azotobactor, Azospirillum*, and PSB may have aided plant physiological processes such as cell division and elongation through indirect activity. Such findings are very similar to the results of Radhika *et al*., (2010) [13], Thumar *et al*., (2013) [19], Pushkar *et al*., (2008) [12], Kumar *et al.* (2009) [9], Bhat *et al*., (2010) [2], Hashemabadi *et al*., (2012) [6] and Rolaniya *et al*., (2017) [14] in African marigold.

Flowering parameters

The flowering parameters showed significant responses to several treatments of integrated nutrient management, according to the statistical analysis of data (Table-2).With respect to days to bud initiation, number of days taken to open first flower (days), number of days taken for 50% flower (days) and duration of flowering (days) in the field. The application of T_{11} (45% RDF + 4 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB) recorded a minimum number of days were taken for days to bud initiation (51.40), number of days taken to open first flower (52.68), number of days taken for 50% flower (59.12) and maximum duration of flowering (62.33) followed by T_8 treatment and longer days taken to days to bud initiation, number of days taken to open first flower (days), number of days taken for 50% flower (days) and minimum duration of flowering (days) was noticed in T_1 (Control) during both the years 2020-21 and 2021-22 as well as in pooled mean basis.

Results clearly show that the combined application of 45% RDF + 4 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB proved to be beneficial for the flowering of plants as compared to other treatments. This might be attributable to the use of nitrogen, phosphorus, potash, vermicompost, and biofertilizers, which favour the production of amino acids, which behave as a precursor to polyamine and a secondary messenger in flower initiation and development. Phytohormones (Auxins, gibberellins) that are generated in plants as a result of chemical and biofertilizers application also influence the synthesis of this amino acid. These results are very similar to the findings of Radhika *et al*., (2010) [13], Thumar *et al*., (2013) [19], Kulkarni (1994) [7], Kumar *et al*. (2009) [9], Kumar and Kumar (2017) [8], Shaikh *et al*., (2018) [16], Chaupoo and Kumar (2020) [4] in African marigold.

Conclusion

According to the results of the experiment, African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda responded effectively to the application of 60 percent RDF + 3 tons ha^{-1} Vermicompost + Azotobacter + Azospirillium + PSB (T_8) in terms of vegetative growth parameters and application of T_{11} (45% RDF + 4 t ha^{-1} Vermicompost + *Azotobacter* + *Azospirillium* + PSB) in term of flowering parameters.

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