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# Potentials of Different Bio-enhancers on the Growth, Flowering, and Yield of African Marigold *(Tagetes erecta L.)*

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## Abstract

A field experiment was conducted to study the effect of "Bio-enhancers on growth, flowering, yield, and biochemical parameters of African Marigold *(Tagetes erecta L.)* cv. African Giant Double Orange" during 2024–25 at Agricultural Research Station, Binjhagiri, Chatabara, under the Institute of Agricultural Sciences, SOA University, Bhubaneswar. The experiment was laid out in randomized block design with nine treatments and three replications. Treatments comprised foliar sprays of Panchagavya (4%), Jeevamrit (5%), Humic Acid (0.2%), and Seaweed Extract (0.15%) applied singly and in combinations. Results revealed that combined application of Panchagavya (4%) + Jeevamrit (5%) + Humic Acid (0.2%) + Seaweed Extract (0.15%) (T9) significantly improved growth (plant height 27.89 cm, stem girth 5.45 cm, plant spread E-W 2750.67 cm², N-S 2735.25 cm²), flowering (earlier bud emergence at 52 days, 50% flowering at 81 days), and yield (flower yield per plant 446.43 g). Biochemical analysis showed maximum chlorophyll content (49.14 SPAD) and carotenoid accumulation (1.82 mg/g) under $T_9$. The study concludes that integrated use of bio-enhancers, particularly $T_9$ [Panchagavya(4%) + Jeevamrit (5%) + humic acid (0.2%) + seaweed extract (0.15%)], enhances productivity and quality of African marigold sustainably.

**Key words**: *Bio-enhancers, Panchagavya, Jeevamrit, Humic acid, Seaweed extract, Marigold*

## Introduction

Floriculture, a vital branch horticulture, is emerging as a high-potential industry due to its ornamental, cultural, and economic significance. Cultivating flowering plants enhances environmental aesthetics and plays a key role in employment generation, income improvement, and foreign exchange through exports. Among the wide range of loose flower, marigold (*Tagetes spp.*) stands out as one of the most extensively cultivated flowers, owing to its hardy nature, ease of cultivation, and diverse utility in religious ceremonies, decorative garlands, essential oil production, and natural dye industries (Bhattacharjee, 2006).

African marigold (*Tagetes erecta L.*), a robust annual belonging to the family Asteraceae, is native to Mexico and Central America and has been widely adapted to Indian conditions. Its large, vibrant blooms in shades of yellow and orange make it highly preferred in the loose flower market. In addition to its decorative value, marigold holds medicinal importance, traditionally used for their antiseptic, anti-inflammatory, and antiparasitic properties (Kumar & Singh, 2003). Marigold is India's most widely cultivated loose flower crop, occupying the most significant area among ornamentals due to their steady demand and adaptability. It enjoys broad acceptance in landscaping, cut flower trade, and value-added industries such as cosmetics and poultry feed additives.

With the rising demand for fresh flowers in religious, social, and commercial sectors and the expanding export market, the need for consistent, high-quality production is becoming increasingly important. However, one of the main challenges in marigold cultivation is the overreliance on chemical fertilizers, which, while promoting rapid growth, often lead to long-term soil degradation, reduced microbial activity, and lower-quality produce. To address this, bioenhancers have gained importance as a sustainable alternative to synthetic agrochemicals. Bioenhancers are natural growth promoters that enhance plant health, productivity, and soil biological activity, contributing to more sustainable floricultural practices. They stimulate plant growth by improving nutrient uptake, enhancing soil microbial diversity, and promoting plant hormone production. Their application in floriculture supports eco-friendly cultivation, improves flower quality, and meets the growing demand for organic and sustainable floral products.

The shift towards organic cultivation practices has led to the adoption of various bio-enhancers such as Panchagavya, Jeevamrit, seaweed extract, and humic acid, each offering unique benefits for plant growth and development. An indigenous formulation, Panchagavya comprises five cow-based products—cow dung, cow urine, milk, curd, and ghee—blended with banana, jaggery, and tender coconut water. It is rich in beneficial microbes, plant growth regulators, and nutrients that help stimulate plant growth, increase resistance to pests and diseases, and enhance flower yield and quality (Natarajan, 2002). Jeevamrit is a fermented organic liquid manure prepared using cow dung, cow urine, pulse flour, jaggery, and a small quantity of native soil. This low-cost input is a potent microbial inoculant that boosts microbial activity in the rhizosphere, enhances nutrient cycling, and improves soil fertility (Subhash *et al.,* 2015). Extracted from brown algae like *Ascophyllum nodosum*, seaweed extract contains natural plant growth hormones such as auxins, cytokinins, gibberellins, micronutrients, and amino acids. It improves vegetative growth, chlorophyll content, and flowering efficiency, especially under stress conditions (Crouch & van Staden, 1993). Humic acid, derived from decomposed organic matter like leonardite, contains fulvic acid, humins, and organic carbon. It enhances nutrient uptake by chelation, improves soil structure, and promotes robust root and shoot development. Floriculture has been shown to increase flower yield and improve overall plant vigor (Zandonadi *et al.,* 2007).

Exploring their potential under field conditions is crucial to establishing ecofriendly protocols for floricultural crop management. Their integration can help meet the increasing demand for high-quality marigolds while preserving soil health and reducing input costs. Therefore, the present study was undertaken to evaluate the effectiveness of selected bio-enhancers, in enhancing growth attributes, floral traits, and yield of marigold.

## Methodology

The study was carried out in the Eastern Coastal Plains, which are typified by a warm and moist climate. The region experiences hot and humid summers, along with mild winters. The experimental period extended from September 2024 to February 2025.

The minimum and maximum temperatures recorded at the study site were 20.26°C and 32.05°C, respectively. The average relative humidity was noted to be 69.5%. The soil was found to be loamy sand with a pH of 5.16. The electrical conductivity (EC) was recorded as 239.3 µS/m.

For this study Seeds of the marigold variety 'African Giant Double Orange' were procured from the State Capital Nursery, Bhubaneswar. Other inputs such as welldecomposed farmyard manure (FYM), urea, di-ammonium phosphate (DAP), muriate of potash (MOP), humic acid, seaweed extract, and the insecticide fipronil were sourced locally from nearby agro-input stores. Panchagavya and Jeevamrit were prepared in the farm using the cow dung and other freshly collected farm wastes.

The experiment was laid out in a Randomized Block Design (RBD) comprising nine treatments, each replicated three times. The experiment involved a total of nine treatments, which included four different concentrations each of Humic Acid (HA) (0.1%, 0.15%, 0.2%, and 0.25%) and Seaweed Extract (SWE) (0.1%, 0.15%, 0.2%, and 0.25%), along with a control.Fertilizers were added according to the treatment where $T_1$ (control) was applied with recommended fertilizer dose of 80:80:80 kg NPK/ha while rest all other treatment were applied with 40:40:40 kg/ha of N, P, and K. Bioenhancers

(Panchagavya, Jeevaamrit, Humic Acid, and Seaweed Extract) were foliar-sprayed twice (15 and 30 DAT) to enhance growth, while $T_1$ (control) and $T_2$ received no bioenhancers. The treatment details are presented in **Table1**. Data were collected in each treatment on growth and flowering parameters. The data were statistically analysed by OPSTAT.

**Table 1: Treatment Details**

| Notations Used | Treatment |
|---|---|
| T1 | Control (80:80:80 kg NPK/ha + 20 t/ha FYM) |
| T2 | 40:40:40 kg NPK/ha + 20t/ha FYM |
| T3 | $T_2$ + Panchagavya 4% + Seaweed extract 0.15% |
| T4 | $T_2$ + Panchagavya 4% + Humic acid 0.2% |
| T5 | $T_2$ + Jivamrit 5% + Seaweed extract 0.15% |
| T6 | $T_2$ + Jivamrit 5% + Humic acid 0.2% |
| T7 | $T_2$ + Panchagavya 4% + Jivamrit 5% + Seaweed extract 0.15% |
| T8 | $T_2$ + Panchagavya 4% + Jivamrit 5% + Humic acid 0.2% |
| T9 | $T_2$ + Panchagavya 4% + Jivamrit 5% + Humic acid 0.2% + Seaweed extract 0.15% |

**Result and Discussion**

The observations on various vegetative parameters revealed significant variations as presented in (Table 2). The tallest plants (27.89 cm) were recorded in $T_9$ which was followed by $T_8$ (23.87 cm) and T6 (23.67 cm). $T_2$ exhibited the shortest plants (22.64 cm), indicating that supplementary bioenhancer treatments significantly enhanced vertical growth. The superior performance of $T_9$ suggests a synergistic effect of integrated organic inputs on plant height, likely due to improved nutrient uptake and hormonal balance. These findings align with *Patel et al. (2022*), who reported a 25% increase in marigold plant height with combined organic amendments. The presence of seaweed extract in T9 may have further stimulated auxin production, promoting stem elongation (*Khan et al., 2009*). The maximum stem girth (5.45 cm) was observed in T9, followed by T8 (4.78 cm) and T7 (4.68 cm). T2 recorded the lowest value (4.43 cm). The enhanced stem girth in T9 can be attributed to the combined effects of humic acid and seaweed extract, which likely improved cell division and vascular tissue development. *Archana et al. (2023)* reported similar results in Asiatic Lilium, where seaweed extract application increased stem diameter by 18%. Humic acid is known to enhance cell wall plasticity and nutrient absorption, contributing to structural robustness (*Canellas et al., 2015)*. T9 exhibited the highest plant spread (E-W) which was found to be 2750.67 cm, compared to T6 (2096.76 cm) and T5 (1844.00 cm) while T2 showed the least expansion (E-W) (1550.44 cm). Similarly maximum plant spread (N-S) was recorded in T9 (2735.25 cm) which was followed by T6 (2078.90 cm) while T2 exhibited the lowest plant spread (1532.50 cm). The wider spread in T9 suggests improved lateral growth due to enhanced photosynthetic efficiency and nutrient mobilization. Singh *et al.* (2021) observed analogous results in chrysanthemums, where humic acid and seaweed extracts increased canopy expansion by 30%. The cytokinin-like compounds in Panchagavya may have further promoted lateral bud activation (*Nardi et al., 2016*). T9 produced the highest number of primary branches (16.00 per plant), significantly surpassing T8 (9.38) and T7 (9.34). T2 had the fewest branches (7.53). The prolific branching in T9 may result from the cytokinin-like effects of Panchagavya and Jivamrit, which are known to break apical dominance. *Kumar et al. (2020)* documented a 40% increase in branch proliferation in roses treated with similar organic inputs. Seaweed extract, rich in growth hormones, likely further amplified this effect (*Battacharyya et al., 2015*).

**Table 2: Effect of bio-enhancers on vegetative characteristics of African marigold**

| Treatments | Plant height (cm) | Basal stem diameter (cm) | Plant spread (East-West) (cm$^2$) | Plant Spread (North – South) (cm$^2$) | Number of primary branches per plant |
|---|---|---|---|---|---|
| $T_1$ | 22.75 | 4.45 | 1698.76 | 1680.30 | 8.00 |
| $T_2$ | 22.64 | 4.43 | 1550.44 | 1532.50 | 7.53 |
| $T_3$ | 23.43 | 4.55 | 1763.00 | 1758.20 | 8.45 |
| $T_4$ | 23.45 | 4.58 | 1795.00 | 1780.45 | 9.00 |
| $T_5$ | 22.69 | 4.57 | 1844.00 | 1825.80 | 8.55 |
| $T_6$ | 23.67 | 4.65 | 2096.76 | 2078.90 | 8.57 |
| $T_7$ | 23.58 | 4.68 | 1899.00 | 1875.60 | 9.34 |
| $T_8$ | 23.87 | 4.78 | 1742.76 | 1730.40 | 9.38 |
| $T_9$ | 27.89 | **5.45** | **2750.67** | **2735.25** | **16.00** |
| SEm (□) | 0.18 | 0.05 | 53.07 | 51.24 | 0.25 |
| C.D. (at 5%) | 0.59 | 0.17 | 159.21 | 153.70 | 0.74 |

**Table 3: Effect of bio-enhancers on flowering characteristics of African Marigold**

| Treatments | Days to first bud emergence (days) | Days to 50% flowering (days) | Individual flower diameter (cm) | Individual flower weight (g) | Yield per plant (g) |
|---|---|---|---|---|---|
| $T_1$ | 56.65 | 89.67 | 6.19 | 8.28 | 311.00 |
| $T_2$ | 54.63 | 88.63 | 6.12 | 8.22 | 299.75 |
| $T_3$ | 53.00 | 87.34 | 6.39 | 9.74 | 317.41 |
| $T_4$ | 52.00 | 83.32 | 6.65 | 10.09 | 365.14 |
| $T_5$ | 53.00 | 84.00 | 6.47 | 9.48 | 345.60 |
| $T_6$ | 52.30 | 84.22 | 6.86 | 9.35 | 320.35 |
| $T_7$ | 51.00 | 85.00 | 6.48 | 9.48 | 329.94 |
| $T_8$ | 42.00 | 80.00 | **7.67** | 11.57 | 335.28 |
| $T_9$ | 52.00 | 81.00 | 6.88 | **13.95** | **446.43** |
| SEm (□) | 0.26 | 0.36 | 0.04 | 0.18 | 3.29 |
| C.D. (at 5%) | 0.78 | 1.24 | 0.19 | 0.85 | 15.46 |

The observations on various flowering parameters revealed significant variations as presented in (Table 3). $T_8$ achieved the earliest bud emergence (42.00 days), while $T_1$ took the longest (56.65 days). Treatments $T_4$ (52.00 days) and $T_6$ (52.30 days) also showed accelerated budding compared with the control. The reduced time to bud emergence in T8 suggests that Panchagavya and humic acid may hasten physiological maturity by optimizing nutrient assimilation. *Meena et al. (2021*) reported similar outcomes in gladiolus, where humic acid improved root efficiency and nutrient uptake, leading to earlier flowering (*Rose et al., 2014*). $T_8$ reached 50% flowering earliest (80.00 days), compared with $T_1$ (89.67 days). Treatments $T_4$ (83.32 days) and $T_6$ (84.22 days) also showed significant reductions in flowering time. *Sharma et al. (2023)* noted similar results in gerbera, attributing accelerated flowering to cytokinins in seaweed extracts *(Mancuso et al., 2006).* $T_8$ produced the largest flowers (7.67 cm), while the $T_2$ recorded the lowest flower diameter (6.12 cm). Treatments $T_6$ (6.86 cm) and $T_4$ (6.65 cm) also showed notable increases. The larger flower size in $T_8$ may result from improved cell expansion due to humic acid's role in water retention and nutrient availability. *Gupta et al. (2022)* reported comparable findings in orchids, where humic acid increased flower diameter by 20% (*Arancon et al., 2012*). Treatment $T_9$ exhibited the highest individual flower weight (13.95 g), followed by $T_8$ (11.57 g) and $T_4$ (10.09 g). While $T_2$ had the lowest weight (8.22 g). The significant increase in flower weight in $T_9$ can be attributed to the combined effects of organic amendments, which improved nutrient uptake and biomass accumulation. The seaweed extract in $T_9$ likely enhanced carbohydrate translocation to the flowers, increasing their weight (*Zhang & Ervin, 2008*). Similar results were reported by *Ertani et al.* (2014) in ornamental plants. The highest yield per plant (446.43 g) was recorded in $T_9$, followed by $T_4$ (365.14 g) and $T_6$ (345.60 g). Treatment $T_2$ yielded the least (299.75 g). The significant increase in yield in $T_9$ can be attributed to the synergistic effects of organic amendments, which likely improved nutrient availability, photosynthesis, and flower size. The combined application of seaweed extract and humic acid may have enhanced root development and nutrient uptake, leading to higher biomass accumulation. These findings align with *Sharma et al.* (*2022),* who reported a 30–40% yield increase in gerbera with similar organic treatments. The seaweed extract in $T_9$ likely enhanced root development, further supporting higher yields (*Rouphael et al., 2018).*

Postharvest and biochemical parameters are presented in Table 4. Under room-temperature conditions, treatment T8 recorded the longest shelf life (16.69 days), followed by T7 (16.35 days) and T6 (16.00 days), whereas T2 had the shortest shelf life (12.25 days). In cold storage, T9 exhibited the maximum shelf life (23.46 days), followed by T8 (22.25 days) and T7 (21.82 days), while T2 again recorded the minimum value (17.30 days). The extended shelf life in T8 and T9 may be attributed to delayed senescence due to the antioxidant properties of humic acid and the improved physiological status achieved under integrated organic nutrition. The integration of bio-enhancers such as Jeevamrit, humic acid, and seaweed extract has been reported to reduce ethylene production and microbial decay, thereby prolonging vase life in chrysanthemum and other ornamentals (Mehta et al., 2022; Verma et al., 2023).

Treatment T9 also exhibited the highest chlorophyll content (49.14 SPAD), followed by T8 (36.82 SPAD), whereas the lowest chlorophyll content was recorded in T2 (26.81 SPAD). The greater chlorophyll concentration in T9 suggests enhanced photosynthetic efficiency due to the combined effects of seaweed extract, rich in cytokinin-like compounds, and humic acid, which improves micronutrient (especially iron) availability (Chen et al., 2004; Verma et al., 2022).

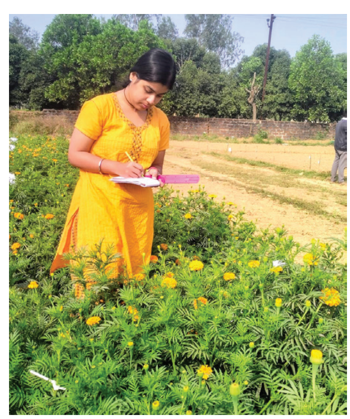
Carotenoid content was highest in T8 (2.99 mg $g^{-1}$), followed by T7 (1.86 mg $g^{-1}$) and T5 (1.67 mg $g^{-1}$), with the lowest value in T2 (1.29 mg $g^{-1}$). The elevated carotenoid levels in T8 indicate improved antioxidant activity and stress tolerance, likely due to the presence of humic acid and Jeevamrit, which enhance secondary metabolite production. Carotenoids play a critical role in photoprotection and flower colour intensity, as reported by Kumar et al. (2021) in lilies.

**Table 4: Effect of bio-enhancers on post-harvest shelf life and biochemical parameters of African marigold**

| Treatments | Shelf life at room temperature (days) | Shelf life (Cold Storage) (days) | Chlorophyll content (SPAD) | Carotenoid (mg/g) |
|---|---|---|---|---|
| T1 | 12.65 | 17.33 | 28.86 | 1.31 |
| T2 | 12.25 | 17.30 | 26.81 | 1.29 |
| T3 | 13.35 | 19.24 | 35.38 | 1.36 |
| T4 | 15.08 | 20.00 | 29.84 | 1.47 |
| T5 | 13.68 | 18.67 | 33.43 | 1.67 |
| T6 | 16.00 | 21.34 | 31.46 | 1.57 |
| T7 | 16.35 | 21.82 | 36.89 | 1.86 |
| T8 | **16.69** | 22.25 | 36.82 | **2.99** |
| T9 | 15.77 | 23.46 | **49.14** | 1.82 |
| SEm | 0.15 | 0.26 | 0.58 | 0.01 |
| C.D.(at 5%) | 0.74 | 0.78 | 1.68 | 0.03 |

## Conclusion

The study conclusively demonstrates that $T_9$ [$T_2$ (40:40:40 kg NPK/ha +20t/ha FYM) + Panchagavya 4% + Jivamrita 5% + humic acid 0.2% + Seaweed extract 0.15%] emerged as the most effective treatment, exhibiting significant improvement in plant height, stem girth, flower size, yield, and postharvest longevity of marigold. These findings underscore the potential of organic bioenhancers as sustainable alternatives to conventional fertilizers, offering a viable strategy to boost productivity in ornamental horticulture. Future research could explore the long-term soil health benefits and economic viability of these treatments for commercial marigold cultivation.



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