International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(1): 530-534
www.biochemjournal.com
Received: 12-10-2025
Accepted: 15-11-2025

Rupali Thakur
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India

Sheetal Dogra
Professor, Division of Floriculture and Landscaping, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India

RK Pandey
Professor & Head, Division of Floriculture and Landscaping, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India

Nomita Laisharam
Division of Floriculture and Landscaping, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India

Arvinder Singh
Division of Floriculture and Landscaping, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India

Bhav Kumar Sinha
Professor, Division of Plant Physiology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India

Moni Gupta
Professor, Division of Biochemistry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India

LM Gupta
Professor & Head, Division of Forest Products and Utilisation, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India

Rakesh Kumar
Division of Floriculture and Landscaping, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India

Sourav Sharma
Division of Floriculture and Landscaping, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India

Corresponding Author:
Sheetal Dogra
Professor, Division of Floriculture and Landscaping, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India

Assessing the efficacy of foliar application of biostimulants on growth dynamics of African marigold (*Tagetes erecta* L.)

Rupali Thakur, Sheetal Dogra, RK Pandey, Nomita Laisharam, Arvinder Singh, Bhav Kumar Sinha, Moni Gupta, LM Gupta, Rakesh Kumar and Sourav Sharma

DOI: https://www.doi.org/10.33545/26174693.2026.v10.i1Sg.6996

Abstract
This study was aimed to compare the effects of biostimulants on growth dynamics of marigold (*Tagetes erecta* L.). The experiment was carried out in open field conditions at the Experimental Farm, Division of Floriculture and Landscaping, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha (J&K). A Randomized Complete Block Design (factorial) experiment was laid out to test various concentrations of biostimulants viz., humic acid, seaweed extract and amino acids against a control on three different varieties of marigold. The primary finding was that seaweed extract @ 0.2% was the most effective biostimulant, resulting in the most significant improvements in overall growth dynamics of marigold varieties. Marigold plants treated with the seaweed extract irrespective of varieties showed superior plant height, branching, stem diameter, leaf area, chlorophyll accumulation compared to all other treatments. This high efficacy is attributed to the seaweed extract's rich content of plant hormones and micronutrients, which promotes early vigor and robust development. The study concludes by recommending the inclusion of seaweed extract in marigold cultivation to boost vegetative growth, plant health, and potential yield in marigold.

Keywords: Plant vigor, seaweed extract, phyllotaxy, branching, photosynthetic pigments

Introduction
Marigold stands as a globally significant commercial flower, commanding a large presence in the floriculture industry. It's cultivated on a massive scale for loose flower production in many countries, including Spain, the USA, Switzerland, France, and Germany. In India, the flower was introduced by the Portuguese and quickly became popular because it can easily thrive in various climatic and soil conditions. India is the leading producer of marigold in the world followed by China and Peru. It accounts for an area of 84.2 (000 ha) with production of 935.6 (000 MT) in India, 2022-23 (APEDA, 2024). African marigold (*Tagetes erecta* L.), a member of family Asteraceae/Compositae, originated from North America, is a robust, bushy annual plant featuring upright stems that branch near the apex. It possesses abundant, vibrant green leaves that are gracefully divided into toothed, lance-shaped segments (Aslam *et al.*, 2018) [6]. The flowers come in a wide color spectrum, from lemon yellow to red, bicolour, or bronze, and their prominent buds feature distinct longitudinal grooves (Tiwari *et al.*, 2018) [19]. Due to this versatility, marigolds are highly valued for ornamental gardens, container planting, and general landscaping.

'Biostimulant' is defined as any natural substance or microbial blend applied to crops or soil primarily to improve nutrient efficiency, boost tolerance to abiotic stress, or enhance crop quality, regardless of how many nutrients the substance itself contains (Du Jardin, 2012) [8]. Using plant biostimulants has been shown to positively impact soil by altering its biological, biochemical, and physical properties. Furthermore, biostimulants improve a plant's nutrient use efficiency, leading to increased crop yields (De Pascale, 2017) [7]. They are also known to favorably affect root growth and architecture and enhance the ability of plants to withstand abiotic stress.

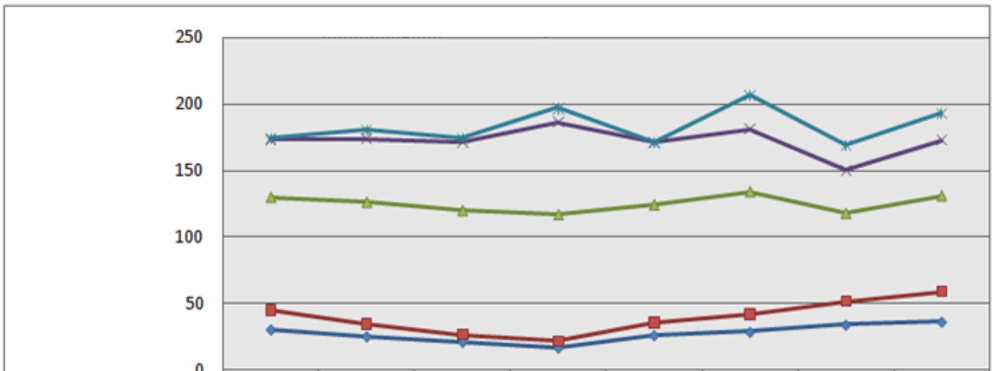
The recent surge in using biostimulants in flower crops reflects a broader industry shift toward sustainable practices in floriculture. These natural substances significantly improve plant performance by boosting water retention, increasing antioxidant levels, enhancing metabolic efficiency, and driving chlorophyll production. Their effectiveness across various flowering stages is linked to their rich composition of polysaccharides, amino acids, vitamins, and nutrients, which notably influences the production of the phytochrome pigment—key to early flowering and flower quality and quantity. Now a recognized and crucial category of horticultural products, biostimulants—which include seaweed extract, amino acids, and humic acid substances—represent an attractive commercial prospect for major companies (Kisvarga *et al.*, 2022) [11]. Recognized as a vital category, biostimulants offer an appealing commercial prospect, with demand projected to surge due to the growth of precision farming and the need for synthetic input alternatives. Given the importance of marigold flowers a study was conducted with an aim to check the efficiency of biostimulants on different growth attributes of marigold (*Tagetes erecta* L.) (Kumar *et al.*, 2021) [13].

Materials and Methods

The present investigation was carried out at the Experimental Farm, Division of Floriculture and Landscaping, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, J&K. Metereological data for the year in which study is conducted is given in figure 1. The experiment was laid out in Factorial Randomized Completely Block Design (RCBD) with varieties being factor I and biostimulants factor II. Three marigold varieties (V_1-'Pusa Bahar', V_2-'Pusa Basanti', V_3-'Pusa Narangi') and three biostimulants with two levels [humic acid (0.1%, 0.2%), seaweed extract (0.1%, 0.2%), and amino acids (0.1%, 0.2%)] were evaluated. Foliar application of biostimulants was done after 25 days of transplanting and, total three sprays at 15 days interval were done. The seeds of marigold varieties were procured from IARI, New Delhi. The nursery raising was done in the month of September and transplanting was done after 30 days, when the seedlings were ready. The investigation was carried out under ambient field conditions. Preliminary site preparation involved intensive tillage to ensure a fine soil tilth, followed by the manual eradication of lithic fragments, debris, and competitive weed flora. The experimental layout consisted of homogenized raised beds. To maintain experimental integrity and mitigate nutrient leaching or treatment drift between plots, individual beds were isolated by a network of drainage and buffer channels.

Statistical Analysis

Statistical analysis of the data collected for different parameters during the present investigation was done as per design of the experiment as suggested by Gomez and Gomez (1984). The critical difference was worked out for 5 per cent (0.05) probability.



	Oct, 2023	Nov,2023	Dec,2023	Jan, 2024	Feb, 2024	Mar, 2024	April, 2024	May, 2024
Rainfall (mm)	0.8	6.2	2.4	10.36	0.12	24.92	18.68	20
RH (Evening)	43.77	48.45	51.9	70	47.2	48.11	33	42.14
RH (Morning)	84.5	91.13	92.95	94.6	88.4	91.43	65.57	71.77
Min. Temperature (°C)	14.6	9.3	5.55	5.14	9.42	13.58	17.92	22.76
Max. Temperature (°C)	30.23	25.05	20.93	16.62	25.98	28.42	33.78	36.02

Fig 1: Meterological data for the year 2023-2024

Results and Discussion

Data was collected at peak flowering stage parameters like plant height, plant spread, number of primary branches, stem diameter and chlorophyll content was recorded. From this study it was clear that biostimulants had a significant effect on the various growth attributes of marigold.

Plant height (cm): Plant height is a key indicator of a plant's growth status and overall vigor. It reflects the cumulative effects of cell division, expansion of meristematic tissues, and elongation of internodes. Data related to plant height of marigold cultivars as influenced by different biostimulants at different levels are shown in Table 1. The maximum plant height was recorded in cv. Pusa Bahar (79.39 cm) while minimum in cv. Pusa Narangi (55.53 cm), among the biostiulants maximum height (78.44 cm) was with with the application of seaweed extract @ 0.2% while the minimum was recorded in control. In case of interaction maximum height was recorded in cv. Pusa Basanti + seaweed extract @ 0.2% which is at par with Pusa Bahar+seaweed extract 0.2%, the lowest was in Pusa Narangi (control). The significant enhancement in plant height observed with seaweed extract treatment can be attributed to the synergistic action of natural growth regulators, such as auxins, cytokinins, and gibberellins, which stimulate cell division and internodal elongation. The present study was in agreement with the findings of Sridhar and Rengasamy (2010) [16] reported in marigold, Hedge *et al.* (2016) in chrysanthemum & Alhasan *et al.* (2021) [4] in *Gerbera.*

Plant spread: Plant spread in marigold refers to the horizontal distance covered by the plant's foliage and branches, measured as the diameter or area that the above-ground parts occupy. For marigolds, particularly in experimental or commercial cultivation, wider spread is considered desirable as it leads to increased floral output and ornamental value. Here, the maximum plant (Table 1.) spread was reported in cv. 'Pusa Basanti' (48.15 cm), while the minimum was in cv. 'Pusa Narangi' (31.59 cm), among the biostimulants maximum was with application of seaweed extract (0.2%). In interaction, recorded in treatment Pusa Basanti + seaweed extract @ 0.2% which is at par with Pusa Bahar + seaweed extract @ 0.2%. As, seaweed extracts contain high concentrations of cytokinins, which are phytohormones responsible for breaking apical dominance. By reducing the dominance of the main vertical shoot, cytokinins stimulate the growth of lateral buds, leading to a bushier plant with a wider horizontal spread. This surge in branching, coupled with enhanced photosynthetic rates and nutrient assimilation, allowed for a more extensive vegetative canopy. These results were in close conformity with the findings of Waly *et al.* (2019) [21] in rosemary, Sumangala *et al.* (2019) [18] in rose, Suchitha *et al.* (2021) [17] in chrysanthemum.

Number of branches: A higher number of primary branches in marigold cultivars is strongly linked to better overall growth, enhanced development, and increased flower yield. Primary branches, which emerge directly from the main stem, result in bushier plants with a larger photosynthetic surface and greater reproductive potential. The maximum number of branches (12.04) was reported in cv. Pusa Basanti among cultivars and the most effective biostimulant was seaweed extract (0.2%). In interaction the effect of seaweed extract (0.2%) on Pusa Basanti (15.42) was superior over other treatments. However, the effect of humic acid and amino acid was better than those untreated plants (Table 2.). The superiority of seaweed extract may be attributed due to high cytokinin content within the biostimulant, which effectively promotes the development of axillary buds. This morphological shift is further supported by the improved nutrient assimilation and elevated chlorophyll levels associated with seaweed application, providing the necessary energetic framework for lateral growth (Ali *et al.*, 2021) [5]. The findings were in agreement with Sorour and Hassan (2023) [15] in *Linum grandiflorum.*

Stem diameter (mm): The maximum stem diameter (9.02 mm) was recorded in cv. 'Pusa Basanti', while the minimum (6.85 mm) was in 'Pusa Narangi'. In interaction the maximum stem diameter (11.67 mm) was in Pusa Bahar +seaweed extract (0.2%) and the minimum (5.06 mm) was in Pusa Narangi with no foliar application of biostimulant. The marked increase in stem girth under the 0.2% seaweed extract treatment is mainly due to enhanced vascular cambium activity. Seaweed-derived cytokinins and auxins stimulate cell division in lateral meristems, promoting secondary growth and a stronger vascular system. This result in improved water and nutrient transport, supports higher biomass and flowering, and enhances lignification, thereby increasing stem strength and reducing lodging. The study were in close conformity with Ozbay *et al.*, (2019) [14] in Ornamental pepper. Also, Verma *et al.*, (2020) [20] reported improved morphological parameters in African marigold. (Table 2.)

Chlorophyll (SPAD value): Chlorophyll content in marigold leaves is a vital indicator of the plant's health, vigor, and photosynthetic capacity, which directly impact growth, development, and flower yield. Chlorophyll molecules absorb light energy for photosynthesis, supporting primary metabolism and the synthesis of floral organs. Among the varieties 'Pusa Basanti' had the maximum SPAD value (51.03) while minimum in 'Pusa Narangi' (48.37). Similar, increase in leaf photosynthetic pigments was reported by Abdou *et al.*, 2018 [2] in gladiolus, Al-hamzawi *et al.* (2019) [3] in *Dianthus chinensis*. The presence of betaines in seaweed extracts acts as a physiological trigger for the plant to synthesize new chlorophyll. Betaines serve as a source of organic nitrogen and help in the stabilization of the thylakoid membranes, which are the sites of light absorption in the chloroplasts (Kularathne *et al.*, 2021) [12]. These bioactive compounds enhance the structural stability of chloroplasts and delay leaf senescence, maintaining a high photosynthetic rate over a longer growth period.

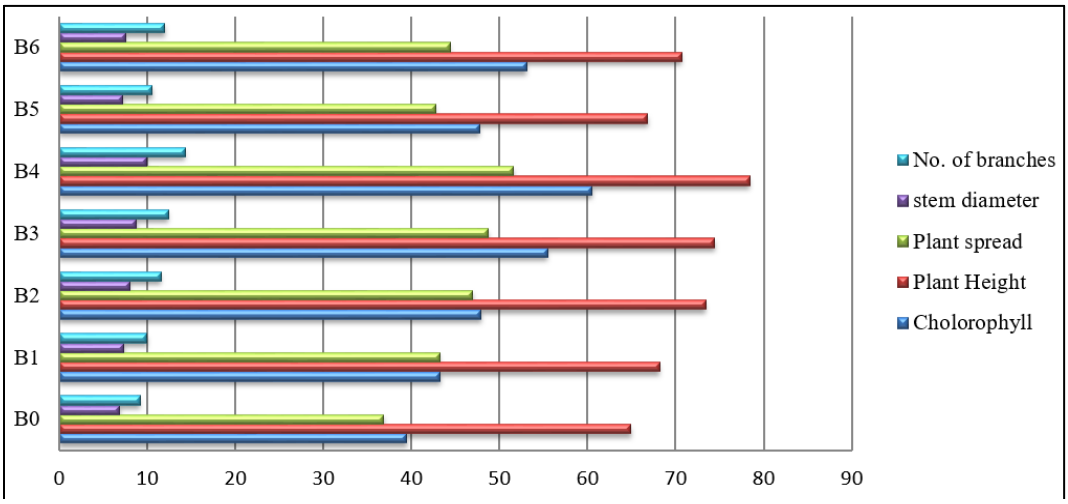


Fig 2: Average effect of biostimulants on African marigold (*Tagetes erecta* L.)

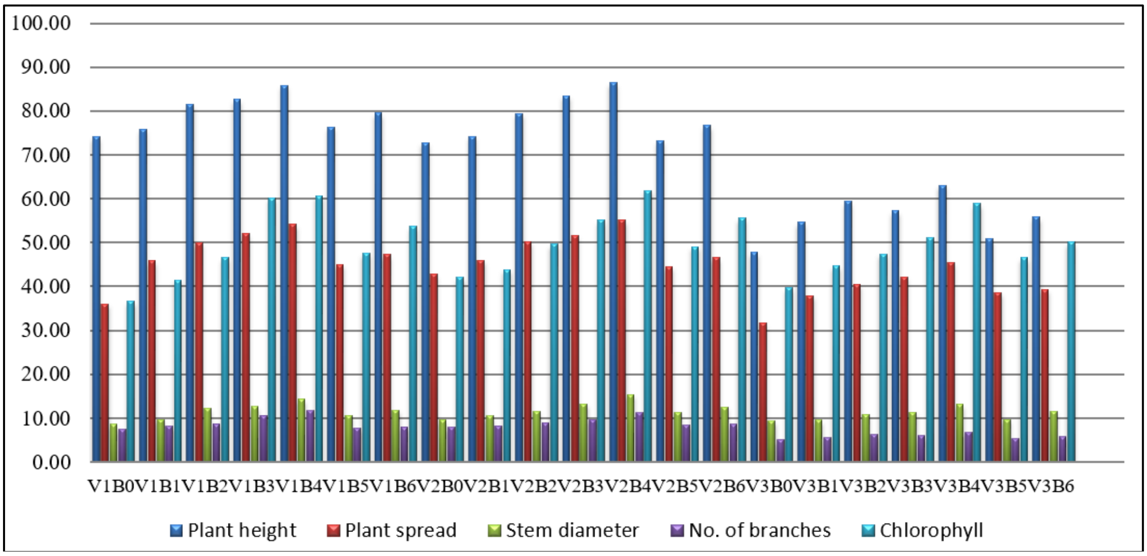


Fig 3: Effect of treatment combination on growth of African marigold (*Tagetes erecta* L.)

Conclusion

The study demonstrates that the integration of specific cultivars with foliar biostimulants significantly enhances the productivity of African marigold (*Tagetes erecta* L.). Among the tested varieties, Pusa Basanti emerged as the superior cultivar, consistently exhibiting higher vegetative vigor compared to Pusa Bahar and Pusa Narangi. The application of Seaweed Extract at 0.2% proved to be the most effective biostimulant treatment. It significantly improved plant height, stem diameter, and primary branching by optimizing hormonal balance and nutrient uptake efficiency. This treatment also maximized chlorophyll synthesis, ensuring a robust photosynthetic framework that supported higher floral loads. Consequently, for commercial marigold cultivation, the use of 0.2% foliar seaweed extract is recommended to achieve optimal growth dynamics.

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