Indian Journal of Hill Farming, (2025); 38(2):7-12.
doi: 10.56678/iahf-2025.38.02.2
ISSN: 0970-6429
ijhfonline.org

RESEARCH ARTICLE

Harmonizing Nutrient Synergy Maximizing Gladiolus Growth and Yield in Hill Terrain through Integrated Nutrient Management

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Abstract

In the 2021-22 agricultural season, the Horticulture Department's Research farm in NU:SAS conducted a study to assess the impact of various organic liquid fertilizers, including effective microorganisms (EM), indigenous effective microorganisms (IEM), and Jeevamrutha, on gladiolus (*Gladiolus grandiflorus* L.) growth in a hilly region. Employing a randomized block design (RBD) with 8 treatments, Treatment T3, which involved 500 mL of activated IEM per square meter, produced the most impressive results. This treatment resulted in the longest spike length (89.62 cm), the highest number of florets per spike (10.47), and the greatest number of corms per plant (1.76). EM significantly reduced critical growth stage durations, such as sprouting (6.83 days), spike initiation (68.48 days), first floret opening (74.24 days), and spike harvesting (7.91 days). Treatment T6, combining 50% recommended dose of fertilizer (RDF) with 50% IEM, yielded the tallest plant height (108.09 cm), extended shelf life (9.35 days), and prolonged vase life in distilled water (11.17 days). Regarding nutrient content, treatment T2 (EM) had the highest nitrogen content in leaves (4.33%), while treatment T3 (IEM) showed the highest phosphorus content (0.011%). In corms, RDF had the highest nitrogen content (3.08%), and Treatment T3 (IEM) had the highest phosphorus content (0.016%). Treatment T2 (EM) had the highest post-harvest soil nutrient availability, with N (961.71 kg ha^{-1}), P (61.96 kg ha^{-1}), and K (516.50 kg ha^{-1}). Additionally, Treatment T5, combining 50% RDF and 50% EM, recorded the highest organic carbon content (2.81%) in the hilly region. Treatment T3 (IEM) showed the most favourable benefit-cost ratio (1:2.46) and the highest net income (₹676,653/ha), highlighting its economic viability and potential for sustainable floriculture management in hilly regions. This study demonstrates the significant impact of organic liquid fertilizers on gladiolus growth, flowering, corm production, soil fertility, and nutrient dynamics in hilly regions.

Keywords: Effective microorganisms, Gladiolus, Indigenous, Jeevamrutha, Organic.

Introduction

Flowers embody essential elements of human life, symbolizing love, joy, and various emotions. They are not only natural gifts enhancing our surroundings with beauty and fragrance, but also hold cultural and commercial significance. India recognizes floriculture as a burgeoning sector, particularly in the North East, with Gladiolus as a prominent ornamental bulbous flower. This regal flower is cherished for its tall stature, vibrant colors, and connotations of strength and honor. The flowers are used in flower arrangements, in bouquets and for indoor decorations. It ranks fourth in the international trade for ornamental cut flowers and ranks first in terms of returns (Sebastian *et al.*, 2018). However, the industry's overreliance on chemical fertilizers has led to soil degradation, emphasizing the need for organic alternatives for sustainable floriculture (GoN, 2018). Organic farming practices have gained momentum globally, with a proven positive impact on soil quality and plant growth. It is a recyclable and sustainable strategy for farming. It is an effective and cost-efficient method to attain sustainable advancement in the agriculture sector (Paull, 2010). In the floriculture sector, organic inputs such as cocopeat, vermicompost, and biofertilizers, along

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How to cite this article: Jangyukala, M., Hemanta, L., Alila, P., Ozukum, L., Devi, M.P., 2025. Harmonizing Nutrient Synergy Maximizing Gladiolus Growth and Yield in Hill Terrain through Integrated Nutrient Management. *Indian J. Hill Farm.*, **38**(2):7-12.

Source of support: Nil

Conflict of interest: None.

Received: 12/03/2025 **Revised:** 28/03/2025 **Accepted:** 10/04/2025

with innovative substances like effective microorganisms (EM), indigenous effective microorganisms (IEM), and Jeevamrutha, have shown promising results. EM, a blend of diverse beneficial bacterial and fungal strains, enhances soil biodiversity and nutrient absorption, thereby boosting crop production and resilience. Lactic acid bacteria within EM suppress harmful microorganisms and enhance soil fertility (Fig 1). Lactic acid is a strong sterilizer (Hidalgo *et al*., 2022) and these bacteria have the ability to suppress Fusarium propagation, which is a harmful microorganism that causes disease problem in continuous cropping.

IEM, a naturally occurring alternative, play a significant role in mineral extraction, waste management, and enhancing soil fertility (Assefa and Tadesse, 2019). Among the different formulations of IEM, Jeevamrutha is widely practiced in organic farming as a cost-effective soil tonic. Prepared using locally available ingredients—fresh cow dung (a source of diverse beneficial microbes), cow urine (rich in nitrogen and growth-promoting substances), jaggery (providing energy for microbial multiplication), gram flour (a protein source), and a small quantity of soil (as a microbial inoculum)—Jeevamrutha creates a favorable environment for the proliferation of indigenous microorganisms. When applied to the soil, it enhances microbial activity, improves nutrient cycling, and makes nutrients readily available for plant uptake (Kumar and Gopal, 2015). Moreover, the practice of intercropping monocots such as Gladiolus with dicots like marigolds proves effective in revitalizing soil health and maximizing economic returns, considering that the shelf life of cut flowers significantly impacts their commercial value (Asrar, 2012). Local florists often resort to affordable natural preservatives, which typically consist of sugar for energy provision, biocides for microbe elimination, and acidifiers for pH regulation. These economical alternatives ensure the longevity of flowers without compromising quality. The shift towards sustainable floriculture practices not only preserves the environment but also enhances economic prospects and promotes healthier living (Wani, *et al*., 2018).

Utilizing organic inputs and innovative methods, the current research emphasizes the significance of sustainable flower production. However, in hilly terrain, limited studies have explored integrated nutrient management for gladiolus, where soil fertility constraints and erosion reduce productivity. This study addresses the gap by examining how harmonizing nutrient synergy can improve growth, yield, and sustainability in gladiolus cultivation.

Materials and Methods

Plant materials and treatments

The experiment was conducted from 2021 to 2022 at the Experimental cum Research Farm in the Department of Horticulture, SAS, Nagaland University, Medziphema Campus, Nagaland. Gladiolus cultivar Candyman was selected for the experiment. Corms of 4 to 5 cm diameter, free from any diseases, were acquired from Pushpanjali Nursery in Midnapur, West Bengal. The experiment followed a randomized block design with an intercrop of African double marigold. The following treatments were administered (Table 1): T_0 (Control or Untreated), T_1 (100% Recommended Dose of Fertilizer, i.e., 40:20:20 gm NPK m^{-2}), T_2 (EM, i.e., 100 mL activated effective microorganism m^{-2}), T_3 (IEM, i.e., 500 mL activated Indigenous Effective

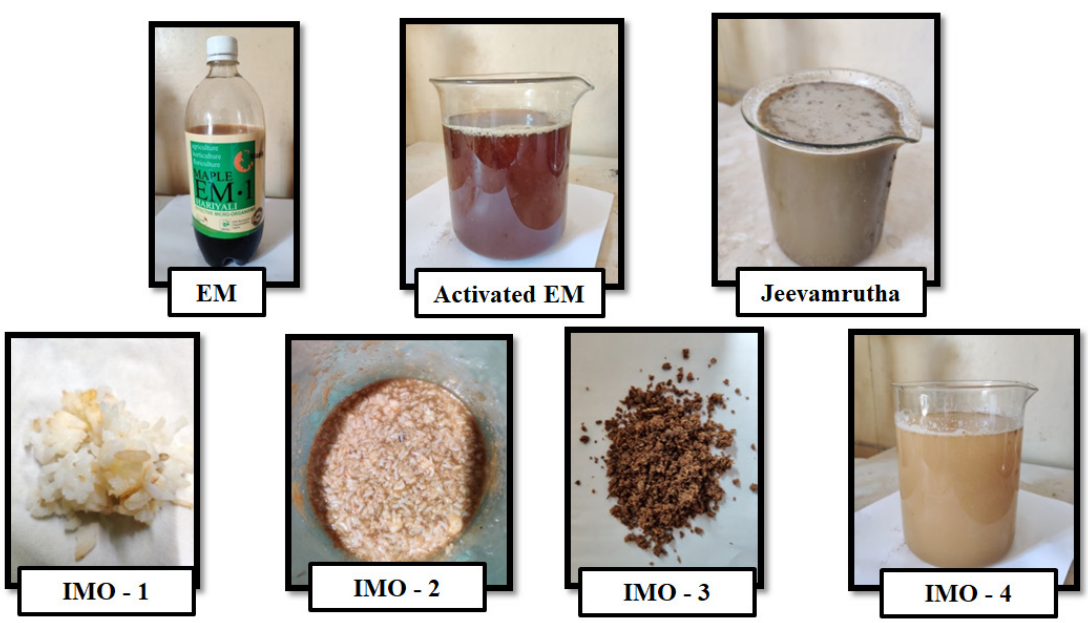

Fig 1: Organic fertilizers *viz*. Effective microorganisms (EM), Jeevamrutha and Indigenous microorganisms (IMO) used for the experiment.

Table 1: To study the effect of different sources of nutrients and their combination on growth, flowering, corm and quality characters.

Treatments	*Days to sprouting*	*Plant height (cm)*	*Days taken for spike initiation*	*Days taken for first floret opening*	*Spike length (cm)*	*No. of florets per spike*	*No. of corms per plant*	*Days to harvesting of spikes*	*Self life*	*Vase life in distilled water*
T_0	10.33	94.11	70.75	78.73	80.42	9.47	0.67	8.82	4.03	7.17
T_1	9.17	83.44	72.68	82.17	73.85	8.07	0.75	10.17	5.08	8.17
T_2	6.83	90.74	68.48	74.24	75.79	9.57	1.24	7.91	9.13	8.50
T_3	8.50	101.30	71.67	79.67	89.62	10.47	1.76	8.94	7.02	9.83
T_4	7.50	97.93	73.33	80.67	78.70	8.83	0.91	9.09	8.25	8.50
T_5	7.83	97.24	70.65	79.83	80.27	9.20	1.18	8.98	7.42	10.83
T_6	7.83	108.09	72.35	78.90	88.58	9.77	0.97	9.97	9.35	11.17
T_7	9.17	87.92	71.38	80.61	78.10	9.00	0.75	9.94	7.23	9.00
SEm±	0.49	4.65	0.88	1.03	3.11	0.33	0.17	0.10	0.13	0.37
CD at 5%	1.49	14.09	2.68	3.14	9.44	1.00	0.53	0.31	0.38	1.12

Microorganism m^{-2}), T_4 (Jeevamrutha 50 mL m^{-2}), T_5 (50% RDF + 50% EM), T_6 (50% RDF + 50% IEM), and T_7 (50% RDF + 50% Jeevamrutha).

The recommended NPK dosage of 40:20:20 g/m^2 was supplied through urea, single super phosphate, and muriate of potash, respectively. The EM organic fertilizer was prepared by mixing 1 liter of Maple EM1 and 1 kg of jaggery in 20 liters of water to activate the EM stock solution. This solution was applied bi-monthly at 15-day intervals starting from the day of planting the corms until spike initiation (Table 2).

Vegetative parameters

The observations on vegetative parameters, viz., days to sprouting and plant height at 20, 40, 60 and 80 days after planting (DAP), were recorded as described below. Five plants per replication were selected and the average was worked out (Table 1).

Days to sprouting

The number of days taken for 50% sprouting was recorded by counting days from the day of planting corms till the corms sprouted in each treatment recorded and then the average days was worked out.

Plant height (cm)

The height of the plant was recorded from the ground to the tip of the longest leaf with the help of a meter scale and the mean height was expressed in centimeters at each stage.

Flowering attributes

Days taken for spike initiation

The number of days taken from planting of corms to spike initiation in the tagged plants was counted and the average days required for spike initiation was worked out.

Days taken for first floret opening

The number of days taken from planting of corms to the opening of the basal floret in each spike was recorded and the average days required for first floret opening was worked out.

Spike length (cm)

Length of spike was measured from the inter-node, next to the top-most leaf, up to the tip of the spike at the fifth opened stage and expressed in centimeters.

Number of florets per spike

The total number of florets per spike was counted and the mean number of florets was recorded.

Days to harvesting of spikes

Days to harvesting of spikes were counted from the day of spike emergence till the harvest stage for five plants and then the average was taken. The spike was harvested at tight bud stage, with basal florets showing colour and at least four leaves on the plant for development of corms and cormels.

Table 2: To study the effect of integrated nutrient management (INM) on nutrient uptake by the plants

Treatments	*Nutrient content gladiolus leaves (%)*		*Nutrient content gladiolus corms (%)*		*Available nutrient status of the soil (kg ha $^{-1}$)*			*Organic carbon (%)*
	N	*P*	*N*	*P*	*N*	*P*	*K*	
T_0	3.65	0.007	2.36	0.012	564.48	38.29	233.33	2.22
T_1	4.22	0.007	3.08	0.013	857.17	35.72	331.10	2.31
T_2	4.33	0.010	2.15	0.014	961.71	61.96	516.50	2.74
T_3	3.57	0.011	2.73	0.016	825.81	48.05	357.47	2.34
T_4	3.08	0.009	2.38	0.011	878.08	44.81	311.43	2.33
T_5	2.63	0.008	2.68	0.011	940.80	38.47	327.32	2.81
T_6	2.67	0.006	2.78	0.010	919.89	42.72	326.70	2.14
T_7	3.24	0.006	3.06	0.010	857.17	39.57	333.93	2.31
SEm±	0.33	0.00	0.17	0.00	48.29	4.13	45.58	0.09
CD at 5%	0.99	0.00	0.53	0.00	146.47	12.52	138.27	0.29

Corm parameters

Number of corms per plant

From the observational five plants, the total number of corms produced from all the sprouts arising from a mother corm was counted and the average number of corms was worked out.

Quality parameters

Self life

The selected five plants per replication in the field were tagged and the time till 70 % of the florets start to wilt was counted and the average was worked out.

Vase-life in distilled water

Vase-life of cut marketable gladiolus spikes was observed in distilled water and expressed in days. The spikes were harvested with the help of secateurs, retaining four leaves on the cut stem when the first floret starts to open and show colour and the cut ends were immediately kept in distilled water at room temperature. In the laboratory, the flower spikes were kept in vases filled with distilled water to study the life of the spike in distilled water without any chemicals. The vase-life in days was calculated from the date of harvesting of the spike to the senescence of the last floret.

Nutrient Uptake by Plants and the State of Soil Fertility

The soil samples were collected from the experimental site at 0 to 15 cm depth and air dried in shade, ground with pestle and mortar, passed through 2 mm sieve and stored in polythene-lined bags. The study was done before planting and after harvest of the crop (Table 2).

Soil samples were analyzed for available nitrogen, phosphorus, potassium, pH, electrical conductivity, and organic carbon. Available nitrogen was determined by the alkaline $KMnO_4$ method (Subbiah and Asija, 1956), where the released ammonia was trapped in boric acid and titrated with standard HCl. Available phosphorus was estimated following Bray and Kurtz (1945) using P-extractant and activated charcoal, with the intensity of the blue color measured spectrophotometrically at 660 nm. Available potassium was extracted with neutral ammonium acetate and quantified using a flame photometer (Hanway and Heidal, 1952). Soil pH was measured in a 1:2.5 soil-water suspension with a digital pH meter, and electrical conductivity was determined in the soil-water extract using a conductivity meter (Jackson, 1973). Organic carbon was analyzed by the Walkley and Black (1934) chromic acid wet oxidation method, with results expressed as percentage carbon.

For plant nutrient uptake studies, index leaves were sampled at spike emergence, thoroughly cleaned, dried, ground, and analyzed for nitrogen, phosphorus, and potassium. Nitrogen was estimated using the Micro-Kjeldahl method (Jackson, 1973), which involves digestion, distillation, and titration. Phosphorus was determined from di-acid digests (HNO_3–$HClO_4$) using the vanadomolybdate yellow color method, while potassium was measured in the same digests using a flame photometer (Johnson and Ulrich, 1959).

Corms were harvested 60 days after flowering, identified at maturity by leaf browning and wilting. The corms were washed, dried, ground, and analyzed for NPK content using the same methods applied for leaf samples. Results for both leaf and corm nutrient contents were expressed on a dry-weight basis.

Results and discussion

Growth Characteristics

Diverse treatments led to distinctive impacts on the growth attributes. Notably, treatment T2 (100 ml activated EM m-2)

Table 3: Influence of different nutrient sources on the economics of cultivation

Treatments	*Cost of cultivation*			*Yield of corms (no. of corms/ha)*	*Value of corms (₹/ha)*	*Yield of cormels (t/ha)*	*Value of cormels (t/ha)*	*Spikes/ha*	*Value of spikes /ha*	*Gross income (₹/ha)*	*Net income (₹/ha)*	*Benefit cost ratio*
	Fixed cost (₹/ha)	*Treatment cost (₹/ha)*	*Total cost (₹/ha)*									
T_0	245000	0	245000	44917	134751	0.28	7119	54222	542220	684090	439090	1.79
T_1	245000	62600	307600	49750	149251	0.39	9833	46584	465830	624914	317314	1.03
T_2	245000	89250	334250	82695	248085	0.55	13645	68806	688050	949779	615529	1.84
T_3	245000	30000	275000	117112	351335	0.13	3368	59695	596950	951653	676653	2.46
T_4	245000	10000	255000	60945	182834	0.49	12278	59084	590840	785952	530952	2.08
T_5	245000	75925	320925	78500	235501	0.94	23450	61195	611950	870901	549976	1.71
T_6	245000	46300	291300	64778	194334	0.43	10717	61167	611670	816721	525421	1.80
T_7	245000	36300	281300	50111	150334	0.47	11767	43139	431390	593491	312191	1.11

induced the earliest corm sprouting (6.83 days), while T6 (50% RDF + 50% IEM) showcased the tallest plant stature (108.09 cm), which may be due to the synergistic effect of inorganic nutrients and indigenous microorganisms, improving nutrient uptake efficiency and soil biological activity, ultimately favoring vegetative growth. Similar results were reported by Xu et al. (2000), who observed enhanced growth when EM was integrated with chemical fertilizers.

Blossoming Characteristics

Significant variations were observed in flowering parameters. Notably, T2 (100 ml activated EM m-2) resulted in the shortest duration for spike initiation (68.48 days), first floret opening (74.24 days), and the quickest spike harvesting (7.91 days). T3 (500 ml activated IEM m-2) manifested the longest spike length (89.62 cm) and the highest floret count per spike (10.47), suggesting that IEM plays a key role in nutrient mineralization and soil fertility improvement, supporting floral development (Javaid and Bajwa 2011).

Attributes of the Gladiolus Plant Corm and Cormel

The experimentation unveiled that T3 (500 mL activated IEM m-2) yielded the highest corm count per plant (1.76). This aligns with findings that organic amendments enriched with indigenous microbes promote balanced nutrition, carbohydrate accumulation, and corm multiplication (Singh *et al*. 2018).

Gladiolus plant's quality standards

T_6 (50% RDF + 50% IEM) displayed the longest shelf life (11.00 days) and the extended vase life (9.35 days). The improved post-harvest longevity may be attributed to balanced nutrient availability that enhances structural integrity, water absorption, and delayed senescence of florets, as also reported in cut flower studies by Kumar *et al.* (2017).

Nutrient Uptake by Plants and the State of Soil Fertility

In terms of soil fertility, T_2 (100 mL activated EM m-2) exhibited the highest available nitrogen content (961.71 kg ha^{-1}), available phosphorus content (61.96 kg ha^{-1}), and available potassium content (516.50 kg ha^{-1}), along with the maximum EC value (0.66 dSm^{-1}). T_7 (50% RDF + 50% Jeevamrutha) recorded the peak pH value of 6.47. T_5 (50% RDF + 50% EM) demonstrated the maximum soil organic carbon (2.81%). Additionally, T_2 (100 mL activated EM m^{-2}) presented the highest nitrogen content in leaves (4.33%), T_3 (500 mL activated IEM m^{-2}) displayed the maximum phosphorus content (0.011%), and T_1 (100% RDF) exhibited the highest potassium content (2.24%). Concerning corms, T_1 (100% RDF) yielded the highest nitrogen content (3.08%), T_3 (500 ml activated IEM m^{-2}) showcased the maximum corm phosphorus content (0.016%), and T_6 (50% RDF + 50% IEM) displayed the highest potassium content (2.02%).

The combined influence of microbial inoculants and organic inputs appears to enhance nutrient solubilization and uptake efficiency (Ghosh *et al*., 2015).

Benefit-Cost Ratio of Cultivation

The cultivation of gladiolus proved most profitable with T_3 (500 mL activated IEM m^{-2}), resulting in a net return of ₹ 676,653 and a B:C ratio of 2.46. This demonstrates that integrating IEM into floriculture not only improves productivity but also enhances economic returns, supporting earlier reports that microbial-based nutrient management reduces dependency on chemical fertilizers while sustaining profitability (Singh *et al.* 2018 and Kumar *et al.* 2017) (Table 3).

Conclusion

The study demonstrated that the application of Effective Microorganisms (EM) and Integrated Effective Microorganisms (IEM) significantly improved the growth, flowering, and corm attributes of gladiolus, with T2 (100 ml activated EM m^{-2}) and T5 (50% RDF + 50% EM) showing the best physiological responses, while T3 (500 ml activated IEM m^{-2}) proved most profitable with the highest B:C ratio. Integrated organic liquid inputs were found to be superior to sole inorganic fertilizers, as they enhanced soil fertility by maintaining higher levels of available NPK, soil organic carbon, EC, and pH, thereby supporting sustainable production. These findings align with previous studies highlighting the positive impact of EM and organic inputs on crop performance and soil health (Al-Amri, 2021; Tejada et al., 2014; Yuan et al., 2023). Thus, integrating EM and IEM with chemical fertilizers can be recommended as a sustainable and economically viable nutrient management strategy for gladiolus cultivation.

Acknowledgement

The authors are grateful to the Department of Horticulture, NU: SASRD and the Ministry of Tribal Affairs, Scholarship Division, under the scheme NFST, for providing research materials and financial assistance.

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