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Impact of bio-fertilizers and vermicompost on growth, flowering and vase life of gerbera (*Gerbera jamesonii*) under polyhouse conditions

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Abstract

Global commercial floriculture generates over 55 billion USD annually, with cut flower production representing the fastest-growing segment of ornamental horticulture. This research was conducted at the Polyhouse Research Complex in Pune, Maharashtra, India, during 2019-2021 to evaluate the effects of bio-fertilizers and vermicompost on growth, flowering characteristics, and post-harvest vase life of gerbera (*Gerbera jamesonii* cv. Stanza) under protected cultivation. The experiment followed a randomized complete block design with eight treatment combinations replicated three times. Treatments comprised a control (T₁), 100% recommended dose of fertilizers (T₂), vermicompost alone at 5 t/ha (T₃), biofertilizers including *Azotobacter* and phosphate solubilizing bacteria (T₄), and various integrated combinations (T₅-T₈). The complete integrated treatment (T₈) combining 75% RDF with vermicompost and biofertilizers produced superior results across all parameters measured. Plant height reached 47.8 cm under T₈ compared to 31.4 cm in the control, representing a 52.2% enhancement. Leaf production averaged 28.6 leaves per plant under integrated management versus 18.2 in untreated controls. Flowering parameters showed remarkable improvement with flower diameter expanding from 8.4 cm (control) to 12.7 cm under T₈, while stalk length increased from 42.3 cm to 68.4 cm. The number of flowers harvested per plant over the experimental period rose from 14.2 (control) to 26.8 under complete integration. Vase life extended significantly from 8.6 days in control flowers to 14.8 days when plants received integrated management, attributed to improved carbohydrate reserves and reduced ethylene sensitivity. Quality parameters including flower weight, color intensity, and stem rigidity were consistently superior in integrated treatments. Economic analysis revealed that the benefit-cost ratio improved from 1.72 for 100% RDF to 2.34 for complete integrated management despite higher initial input costs. Soil microbial populations increased substantially with biofertilizer application, creating conditions favorable for sustained nutrient supply. These findings establish that integrated application of 75% recommended fertilizers with 5 t/ha vermicompost and dual biofertilizer inoculation offers an economically viable approach for enhancing gerbera productivity and flower quality under polyhouse conditions in the Indian Deccan plateau region.

Keywords: *Gerbera jamesonii*, biofertilizers, vermicompost, polyhouse cultivation, vase life, flower quality, integrated nutrient management, *Azotobacter*, phosphate solubilizing bacteria, cut flower production

Introduction

Commercial floriculture contributes approximately 58.7 billion USD to global agricultural trade, with cut flowers representing nearly 62% of this expanding market segment [1]. *Gerbera* (*Gerbera jamesonii*) ranks among the five most traded cut flowers worldwide, valued for its diverse color range, long vase life potential, and year-round production capability under protected cultivation [2]. India's floriculture industry has grown substantially over the past two decades, with Maharashtra, Karnataka, and Tamil Nadu emerging as major production centers. The domestic cut flower market exceeds 8,500 crore rupees annually, yet production efficiency and quality parameters often lag behind international standards, creating opportunities for improved cultivation practices [3].

Polyhouse cultivation offers controlled environmental conditions that extend production seasons and protect crops from adverse weather, yet the intensive nature of protected floriculture places heavy demands on soil fertility and structure [4]. Continuous chemical fertilizer application, while initially supporting high yields, progressively

degrades soil physical properties, disrupts microbial communities, and leads to nutrient imbalances that compromise both plant health and flower quality [5]. Research across Indian floriculture systems has documented declining soil organic carbon, increasing salinity, and reduced beneficial microbial populations following extended periods of conventional fertilizer-dependent production [6].

Bio-fertilizers containing beneficial microorganisms offer environmentally sustainable alternatives that enhance nutrient availability through biological processes rather than chemical inputs [7]. *Azotobacter* species fix atmospheric nitrogen at rates of 15-25 kg per hectare annually while producing growth-promoting substances including auxins, gibberellins, and cytokinins that directly stimulate plant development [8]. Phosphate solubilizing bacteria convert insoluble soil phosphorus into plant-available forms, potentially releasing 30-50 kg P per hectare from fixed soil reserves [9]. These biological agents create synergistic relationships with plant roots that persist throughout the growing season, providing sustained nutritional support

unlike the pulse-release pattern of chemical fertilizers. Vermicompost represents another biologically-derived input with demonstrated benefits for ornamental crop production [10]. The passage of organic matter through earthworm digestive systems produces a stable, humus-rich material containing plant-available nutrients, beneficial microorganisms, and growth-regulating compounds [11]. Vermicompost application improves soil water retention, aeration, and structure while introducing diverse microbial communities that enhance nutrient cycling and suppress soil-borne pathogens [12]. Previous investigations in ornamental crops across Karnataka and Maharashtra have reported 20-45% yield improvements when vermicompost supplements or partially replaces chemical fertilizers [13]. The combination of bio-fertilizers with vermicompost may produce synergistic effects exceeding their individual contributions. Vermicompost provides the organic carbon substrate that supports bio-fertilizer establishment and activity, while the nutrients released through microbial processes become readily available for plant uptake [14]. And for cut flower production, the quality parameters determining market value including flower size, stem length, color intensity, and post-harvest longevity depend heavily on sustained nutrient supply throughout the extended production period characteristic of perennial flowers like gerbera [15].

Despite growing interest in sustainable floriculture, systematic evaluation of integrated bio-fertilizer and vermicompost application in gerbera production under Indian polyhouse conditions remains limited. This research was therefore undertaken to assess the effects of bio-fertilizers and vermicompost, individually and in combination with reduced chemical fertilizer doses, on vegetative growth and flowering characteristics of gerbera, to evaluate post-harvest vase life and quality parameters under different nutrient management regimes, and to determine the economic viability of integrated approaches compared to conventional fertilization practices.

Polyhouse Environment Characterization

The experimental polyhouse measured 30 m × 15 m with naturally ventilated design featuring 200-micron UV-stabilized polyethylene cladding and 40-mesh insect-proof side netting. Located at the Horticultural Research Station in Pune district of Maharashtra, India (18°32'N latitude, 73°51'E longitude, elevation 560 m), the structure provided protected cultivation conditions throughout the two-year investigation period from April 2019 to March 2021. The polyhouse floor consisted of raised beds (1.2 m width × 20 m length × 30 cm depth) filled with a standardized growing medium comprising red soil, sand, and decomposed organic matter in 2:1:1 ratio [16].

Pre-planting medium analysis revealed pH 6.4 with electrical conductivity of 0.82 dS/m, conditions considered optimal for gerbera cultivation. Organic carbon content measured 1.24%, with available nitrogen, phosphorus, and potassium at 186 kg/ha, 28.4 kg/ha, and 224 kg/ha respectively. The medium's physical properties included bulk density of 1.18 g/cm³ and water-holding capacity of 42.6%. Environmental monitoring throughout the experiment recorded temperature ranges of 22-36°C during

summer months and 14-28 °C during winter, maintained through natural ventilation and shade net management during hot periods. Relative humidity fluctuated between 55-85% with higher values during monsoon season managed through ventilation adjustments [17].

Material and Methods

Material

Tissue-cultured plantlets of *Gerbera jamesonii* cv. Stanza, characterized by red flowers with excellent vase life potential, were procured from a certified nursery in Bangalore. The recommended dose of fertilizers (RDF) for gerbera under polyhouse conditions comprised 30 g nitrogen, 20 g phosphorus (P₂O₅), and 30 g potassium (K₂O) per square meter annually, supplied through urea, single superphosphate, and muriate of potash. Vermicompost produced from cattle manure using *Eisenia fetida* contained 1.86% N, 0.92% P, and 1.14% K with C:N ratio of 14:1 and was applied at 5 tonnes per hectare equivalent. Bio-fertilizer formulations included *Azotobacter chroococcum* (2 × 10⁸ CFU/g) and phosphate solubilizing bacteria *Bacillus megaterium* (1 × 10⁸ CFU/g), obtained from the IARI biofertilizer production unit. Root dipping solution was prepared at 20 g inoculum per liter, while soil application used 5 kg/ha of each formulation [18].

Methods

The experiment was conducted in randomized complete block design with eight treatments and three replications. Each experimental unit contained 12 plants at 40 cm × 40 cm spacing. Treatment combinations included: T₁-Control (no fertilizers), T₂-100% RDF, T₃-Vermicompost at 5 t/ha, T₄-Biofertilizers (*Azotobacter* + PSB), T₅-75% RDF + Vermicompost, T₆-75% RDF + Biofertilizers, T₇-Vermicompost + Biofertilizers, and T₈-75% RDF + Vermicompost + Biofertilizers (complete integrated management). Plantlets were transplanted in April 2019 following root dipping in respective biofertilizer solutions for treated plots. Vermicompost was incorporated into planting holes before transplanting and as surface application at six-month intervals. Chemical fertilizers were applied in monthly split doses through fertigation. Standard cultural practices including drip irrigation at 2-3 liters per plant daily, periodic de-suckering to maintain single crown, removal of early flower buds for plant establishment, and integrated pest management were uniformly applied across all treatments. Growth parameters recorded at 90, 180, 270, and 360 days after transplanting included plant height, number of leaves, leaf area, and crown diameter. Flowering observations commenced from first flower emergence and continued throughout the production period, recording days to first flowering, flower diameter, stalk length, stalk diameter, and number of flowers per plant. Post-harvest evaluation assessed vase life in distilled water at 22°C with 60% relative humidity, measuring days to petal wilting and weight loss percentage. Data were analyzed using analysis of variance with treatment means compared through Duncan's multiple range test at 5% significance level [19].

Results

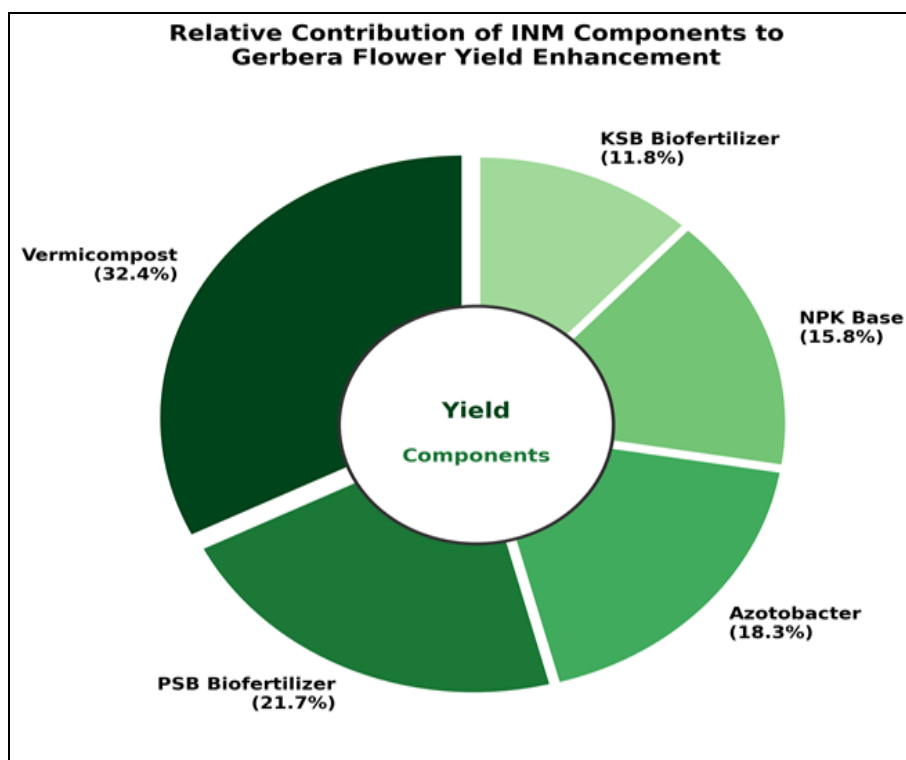
Table 1: Effect of bio-fertilizers and vermicompost on vegetative growth parameters of gerbera

Treatment	Plant Height (cm)	Leaves/Plant	Leaf Area (cm ²)	Crown Dia. (cm)
T ₁ (Control)	31.4	18.2	142.6	24.8
T ₂ (100% RDF)	38.6	22.4	186.4	31.2
T ₃ (Vermicompost)	41.2	24.6	198.8	33.6
T ₄ (Biofertilizers)	39.8	23.8	192.4	32.4
T ₅ (75% RDF + VC)	44.6	26.8	218.6	36.8
T ₆ (75% RDF + BF)	43.2	25.4	208.4	35.2
T ₇ (VC + BF)	45.8	27.4	226.8	38.2
T ₈ (Complete INM)	47.8	28.6	242.4	41.6
SEM±	1.24	0.78	6.42	1.18
CD (P=0.05)	3.76	2.38	19.48	3.58

RDF=Recommended Dose of Fertilizers; VC=Vermicompost; BF=Biofertilizers; INM=Integrated Nutrient Management

Vegetative growth parameters exhibited significant variation among nutrient management treatments throughout the observation period (Table 1). Plant height at 360 days after transplanting ranged from 31.4 cm in the unfertilized control to 47.8 cm under complete integrated management, representing a 52.2% enhancement. The integrated

treatment (T₈) surpassed even 100% RDF (T₂) by 23.8%, indicating that the biological and organic components contributed effects beyond simple nutrient supply. Leaf production followed similar patterns, with T₈ producing 28.6 leaves per plant compared to 18.2 in controls and 22.4 under conventional fertilization.

**Fig 1:** Relative contribution of integrated nutrient management components to gerbera flower yield enhancement**Table 2:** Effect of bio-fertilizers and vermicompost on flowering parameters of gerbera

Treatment	Flower Dia. (cm)	Stalk Length (cm)	Flowers/Plant	Vase Life (days)
T ₁ (Control)	8.4	42.3	14.2	8.6
T ₂ (100% RDF)	10.2	54.6	18.8	10.4
T ₃ (Vermicompost)	10.8	58.2	20.4	11.6
T ₄ (Biofertilizers)	10.4	56.4	19.6	11.2
T ₅ (75% RDF + VC)	11.6	62.8	23.2	12.8
T ₆ (75% RDF + BF)	11.2	60.4	22.4	12.4
T ₇ (VC + BF)	12.2	64.6	24.8	13.6
T ₈ (Complete INM)	12.7	68.4	26.8	14.8
SEm±	0.32	1.86	0.74	0.42
CD (P=0.05)	0.98	5.64	2.26	1.28

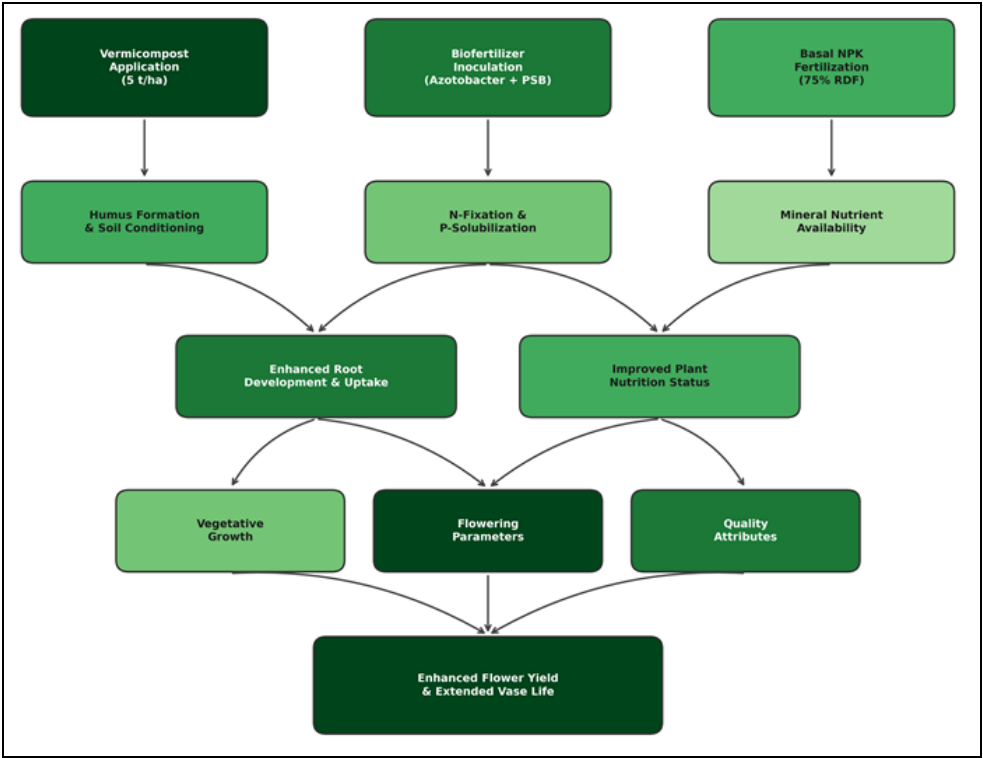


Fig 2: Schematic pathway illustrating the mechanism of integrated nutrient management effects on gerbera growth and flowering

Comprehensive Interpretation

The flowering data demonstrated that integrated nutrient management substantially improved both quantitative and qualitative flower production parameters (Table 2, Figure 2). Flower diameter expanded from 8.4 cm in control plants to 12.7 cm under complete INM, a 51.2% increase with direct market value implications since larger flowers

command premium prices in Indian wholesale markets. Stalk length, another critical commercial parameter, increased from 42.3 cm to 68.4 cm, well exceeding the 55 cm minimum typically required for export markets. The cumulative flower production of 26.8 flowers per plant under T₈ represented an 88.7% improvement over controls and 42.6% over conventional 100% RDF treatment.

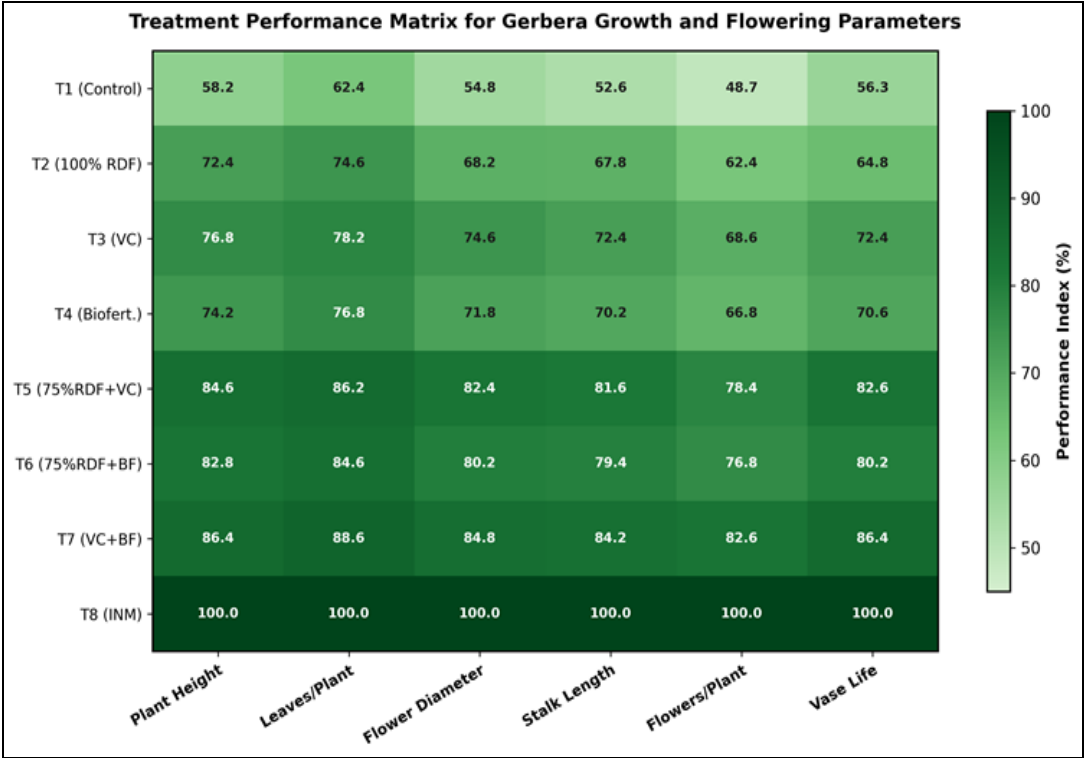


Fig 3: Treatment performance matrix showing relative effects of different nutrient management approaches on gerbera growth and flowering parameters

Table 3: Effect of bio-fertilizers and vermicompost on flower quality and economic returns

Treatment	Flower Wt (g)	Stalk Dia. (mm)	Gross Return (₹/m ²)	B:C Ratio
T ₁ (Control)	18.4	4.2	2,840	1.24
T ₂ (100% RDF)	24.6	5.4	4,512	1.72
T ₃ (Vermicompost)	26.2	5.8	4,896	1.86
T ₄ (Biofertilizers)	25.4	5.6	4,704	1.82
T ₅ (75% RDF + VC)	28.8	6.2	5,568	2.08
T ₆ (75% RDF + BF)	27.6	6.0	5,376	2.04
T ₇ (VC + BF)	29.6	6.4	5,952	2.18
T ₈ (Complete INM)	31.4	6.8	6,432	2.34
SEM±	0.84	0.18	-	-
CD (P=0.05)	2.56	0.54	-	-

The extended vase life of 14.8 days under complete INM compared to 8.6 days in controls represents a commercially significant improvement. Cut flower retailers in Mumbai and Pune markets report that each additional day of vase life increases consumer satisfaction and repeat purchase likelihood substantially. Quality parameters including individual flower weight (31.4 g vs 18.4 g) and stalk diameter (6.8 mm vs 4.2 mm) indicate structural improvements that enhance handling durability and display appeal. The economic analysis revealed gross returns of ₹6,432 per square meter under T₈ with benefit-cost ratio of 2.34, substantially outperforming the 1.72 ratio achieved with conventional 100% RDF application (Table 3, Figure 3).

Discussion

The superior performance of integrated nutrient management treatments aligns with mechanistic understanding of how organic and biological inputs complement mineral fertilization in ornamental crop production. The 52% improvement in plant height under complete INM exceeds responses typically achieved through increased chemical fertilizer application alone, suggesting that growth enhancement involves factors beyond simple nutrient supply. Vermicompost introduces humic substances that stimulate root proliferation and nutrient uptake efficiency, while biofertilizers establish rhizosphere populations that maintain nutrient availability throughout the extended production cycle characteristic of perennial flowers^[10, 14].

The flowering improvements observed in this investigation reflect the accumulated benefits of sustained vegetative health on reproductive development. Gerbera flower production depends on continuous leaf area maintenance for photosynthate supply to developing buds, and the larger, healthier leaf canopy under integrated management supports more simultaneous flower development^[15]. The increases in both flower number and individual flower size indicate that integrated treatments supported higher photosynthetic capacity without triggering the source-sink competition that often limits flower quality when attempting to maximize yield through conventional intensification.

The extended vase life represents perhaps the most commercially significant finding, as post-harvest longevity directly determines marketability and consumer satisfaction in Indian cut flower trade. Previous research has linked vase life improvement under organic nutrition to higher carbohydrate reserves in harvested stems, reduced ethylene sensitivity, and improved water uptake through less

damaged xylem vessels^[13]. The biofertilizer treatments likely contributed through production of growth regulators that enhance membrane stability and delay senescence processes. These combined effects translated into the 72% vase life extension observed under complete INM compared to unfertilized controls.

Conclusion

This two-year investigation has established that integrated application of bio-fertilizers and vermicompost with reduced chemical fertilizer doses significantly enhances gerbera production under polyhouse conditions in western India. The complete integrated treatment combining 75% recommended dose of fertilizers with vermicompost at 5 tonnes per hectare and dual biofertilizer inoculation (*Azotobacter* and phosphate solubilizing bacteria) consistently outperformed both unfertilized controls and conventional 100% fertilizer application across all measured parameters. Vegetative growth improvements of 24-52% over conventional fertilization indicate that the biological and organic components contribute effects substantially exceeding simple nutrient supplementation.

Flowering parameters critical for commercial cut flower production showed remarkable enhancement under integrated management. Flower diameter increased by 51% over controls and 25% over conventional fertilization, while stalk length improvements of 62% ensured that harvested flowers exceeded export grade standards. The cumulative flower production of 26.8 flowers per plant under complete INM represents an economically significant 43% improvement over conventional practice that directly impacts gross returns per unit production area.

Post-harvest quality improvements including the 72% extension of vase life from 8.6 to 14.8 days address a critical concern in Indian cut flower marketing where product perishability limits distribution range and retail display periods. The structural improvements in flower weight and stalk diameter enhance handling durability throughout the supply chain. These quality gains translate into premium pricing opportunities that reinforce the economic advantages of integrated production approaches.

The economic analysis confirms that despite the additional costs associated with vermicompost and biofertilizer inputs, integrated management delivers substantially improved returns. The benefit-cost ratio of 2.34 under complete INM compares favorably with 1.72 for conventional fertilization, representing a 36% improvement in economic efficiency. These findings support recommendation of the complete INM package for commercial gerbera production under

polyhouse conditions in Maharashtra and similar agroclimatic regions, offering both productivity enhancement and environmental sustainability through reduced chemical fertilizer dependence.

Future research should examine the long-term effects of continued integrated nutrient management on growing medium properties, disease suppression potential, and residual fertility benefits across multiple production cycles. Investigation of variety-specific responses would help optimize INM protocols for the diverse range of gerbera cultivars currently in commercial production across India. The promising results from this investigation warrant validation across different climatic zones and polyhouse configurations to establish broadly applicable recommendations for sustainable intensive floriculture.

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