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# Vermicompost and Vermitea Effects on Fenugreek (*Trigonella foenum-graecum* L.) Growth and Physiological Performance

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## ABSTRACT

Vermicompost, an eco-friendly biofertilizer rich in nutrients, phytohormones, and beneficial organisms, enhances soil properties, crop growth, physiological performance and productivity. This study investigates the impact of vermicompost (VC) and vermitea (VT) treatments on the growth and physiological features of fenugreek plants compared to control plants receiving 100% NPK fertilizer. The experimental treatments included VC as a soil amendment at 60 g ($VC_1$) and 120 g ($VC_2$) per pot and VT as a foliar spray applied three ($VT_1$) or six times ($VT_2$) during growth. Combinations such as $VC_1$+$VT_1$, $VC_1$+$VT_2$, $VC_2$+$VT_1$, and $VC_2$+$VT_2$ were also evaluated. The experiment followed a randomized complete block design with 9 treatments and 4 replicates. Results showed significant improvements in growth parameters, photosynthetic pigments, and shoot constituents, with combined VC+VT treatments outperforming individual applications. The most effective treatment, $VC_2$+$VT_2$, achieved the highest increases in root size (163.47%), stem length (91.00%), branch number (110.08%), leaf number (29.28%), total leaf area (130.92%), dry weight (189.82%), total chlorophyll (134.78%), carbohydrates (19.64%), proteins (35.65%), and phenols (109.11%) in the first season, with similar results in the second season. These findings suggest that integrated VC+VT applications are a powerful, eco-friendly approach to enhancing fenugreek growth and sustainable productivity, potentially benefiting other crops as well.

***Keywords:*** *Bioconstituents, Chemical,Fenugreek,,Growth,NPK,Photosynthetic pigments,Vermicompost Vermitea*

## INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is an annual legume herb from the Fabaceae family that is prized for its nutraceutical characteristics and used as a spice, condiment, vegetable, and medicinal herb (Petropoulos, 2002; Somdutt *et al.*, 2019). Its seeds, the main economic part, are rich in minerals, proteins, lipids, dietary fiber, and bioactive compounds like saponins, galactomannans, alkaloids, polyphenols, and vitamins. These components contribute to its medicinal effects, such as antibacterial, anti-inflammatory, antidiabetic, anticancer, hepatoprotective, hypocholesterolemic, and lactation-promoting properties, while also functioning as emulsifiers, adhesives, and stabilizers in the food industry (Gavahian *et al.*, 2024; Tewari *et al.*, 2024). Agriculturally, fenugreek improves crop rotation, livestock feed, and soil fertility through nitrogen fixation, indicating its flexibility in food, medicine, and agriculture (Sadeghzadeh-Ahari *et al.*, 2009).

The global demand for fenugreek seeds is increasing due to growing awareness of their health advantages and their inclusion in functional foods and herbal products (Tewari *et al.*, 2024). Expanding commercial cultivation is necessary to meet the rising demand for fenugreek and other plants used in traditional medicine, the pharmaceutical sector, and functional foods. However, difficulties such as water shortage, soil and water saltiness, and agricultural pollution severely impede crop output (Motawea, 2024; Nuruzzaman *et al.*, 2025; Wanas *et al.*, 2025).

Agricultural pollution is primarily caused by wrong agricultural practices like overuse of chemical fertilizers, herbicides, and pesticides, which contaminate soil through water runoff, wind, erosion, precipitation, and leaching into groundwater, along with irrigation water tainted by industrial discharge and sewage, further degrade soil quality and damage crops. The environmental and health consequences of such diffuse pollution are significant and require urgent action. Adopting preventative techniques to reduce pollution and related dangers is critical for long-term agricultural and environmental sustainability and human health (Nuruzzaman *et al.,* 2025).

In this regard, vermicompost has emerged as a nutrient-rich organic fertilizer and potent growth stimulant, surpassing traditional composts and chemical fertilizers. Its adoption marks a significant step in reducing dependency on synthetic fertilizers, thereby decreasing environmental pollution and lowering agriculture's carbon footprint. Vermicompost is an organic fertilizer produced through the action of microorganisms and earthworms on organic waste. These organisms convert organic material into nutrient-rich vermicompost, which enhances soil structure, water retention, and aeration, leading to improved crop growth, productivity, and yield quality (Sinha *et al.,* 2009). Vermicomposting is an environmentally friendly process that facilitates the diversion of waste from landfills by earthworms, lowering greenhouse gas emissions while establishing a circular, sustainable waste management system. This technique efficiently converts agro-industrial waste, an abundant source of energy, protein, and important nutrients, into a valuable resource that would otherwise be lost if deposited in landfills (Alshehrei & Ameen, 2021; Mohite *et al.,* 2024).

The importance of vermicompost in modern agriculture and environmental sustainability cannot be overstated. As a nutrient-rich biofertilizer, vermicompost enhances soil fertility, increases crop yields, and aids in effective waste management. Its composition includes essential nutrients like macronutrients (N, P, K, Ca, and Mg) and micronutrients (Fe, Mn, Zn, B, and Cu), along with humic substances and beneficial microbes, which improve soil properties, nutrient availability, and water retention, leading to healthier plants and higher productivity. With a higher cation exchange capacity than traditional compost, vermicompost efficiently retains and releases nutrients over time, ensuring sustained plant nutrition (Kauser & Khwairakpam, 2022; Boruah & Deka, 2023; Mohite *et al.,* 2024). The presence of beneficial microbes, such as nitrogen-fixing bacteria (e.g., *Rhizobium*, *Azotobacter*, *Nitrobacter*, and *Azospirillum*), phosphate-solubilizing bacteria, *Bacillus*, *Pseudomonas,* and *Trichoderma*, with microbial populations ranging from $10^{-2}$ to $10^{-6}$, enables vermicompost to act as both an organic biofertilizer and biopesticide, inhibiting pathogens (Piya *et al.,* 2018; Mohite *et al.,* 2024). Additionally, vermicompost enhances physicochemical soil characteristics like texture, aggregation, bulk density, pH, electrical conductivity, organic matter, and water retention, while reducing soil erosion (Piya *et al.,* 2018). As an organic fertilizer, biofertilizer, and biopesticide, vermicompost supports sustainable and eco-friendly agricultural systems, offering a competitive alternative to traditional practices (Al Ali *et al.,* 2019; Sulaiman & Mohamad, 2020).

Vermicomposting offers significant economic benefits by lowering food production costs by 60–70% compared to chemical fertilizers while providing consumers with safe, chemical-free produce. Vermicompost also accelerates crop growth and reproduction, thereby reducing harvest time and expenses. This improvement enhances farmers' financial stability, enabling them to grow more crops each year (Sinha *et al.,* 2009). Furthermore, it is well recognized that organic fruits and vegetables produced with vermicompost include substances that could enhance human longevity and health (Mie, 2017; Rahman, 2024).

Vermitea, a liquid manure made from vermin-casts (vermicompost), is commonly utilized to improve soil physical characteristics, organic matter, macro- and micronutrients, and beneficial microbes, resulting in increased crop growth, productivity, and yield quality. It improves shoot and root growth rates and total crop yield (Piya *et al.,* 2018; Sulaiman & Mohamad, 2020). Vermitea increases soil microbial diversity and hydrolytic enzymes, including lipases, chitinases, and cellulases, which are produced in earthworm intestines (Saheed *et al.,* 2017). Furthermore, it modulates soil nematode diversity and provides biological control of plant and soil pathogens via microorganisms such as *Actinomycetes, Streptomyces, Trichoderma,* and *Pseudomonas spp*., which are frequently isolated from vermicompost (Saheed *et al.,* 2017; Abou El-Goud, 2020). This study aimed to examine the effects of vermicompost and vermitea, applied individually or in combination, on growth, photosynthesis efficiency, and chemical constituents of fenugreek plants.

## Materials and Methods

### 1. Experimental Layout

Two pot experiments were carried out at the Nursery of the Faculty of Agriculture, Damietta

University, Egypt (31°25'39.1"N, 31°39'06.2"E), during the 2021/2022 and 2022/2023 winter seasons. The study aimed to assess the comparative and combined effects of vermicompost and vermitea on the growth and physiological performance of fenugreek plants (*Trigonella foenum-graecum* L., Giza-2 cultivar). Seeds were obtained from the Legumes Department, Agricultural Research Center, Giza, Egypt. The experimental treatments were as follows:

- $T_1$:Control treatment, with 100% of the recommended NPK fertilizers applied.
- $T_2$: Vermicompost added to the soil at 60 g per pot ($VC_1$).
- $T_3$: Vermicompost added to the soil at 120 g per pot ($VC_2$).
- $T_4$: Vermitea foliar spray (100 ml per plant) applied three times ($VT_1$).
- $T_5$: Vermitea foliar spray (100 ml per plant) applied six times ($VT_2$).
- $T_6$: Combination of $VC_1$ & $VT_1$.
- $T_7$: Combination of $VC_1$ & $VT_2$.
- $T_8$: Combination of $VC_2$ & $VT_1$.
- $T_9$: Combination of $VC_2$ & $VT_2$.

The experiment used 35 cm diameter plastic pots filled with a 3:2:1 (v/v/v) mixture of sand, farm soil, and peat moss, totaling 15 kg per pot. Small limestone gravel (5% by volume) was added at the bottom of each pot. Vermicompost was incorporated into $T_2$, $T_3$, $T_6$, $T_7$, $T_8$, and $T_9$ pots 21 days before sowing to facilitate decomposition. Seeds were sown on November 14$^{th}$, with six seeds per pot. The experiment followed a randomized complete-block design with nine treatments and four replicates, each containing five pots. Two weeks after sowing, seedlings were trimmed to two per pot. Starting at 21 days after sowing (DAS), three times on $T_4$, $T_6$, and $T_8$ plants and six times on $T_5$, $T_7$, and $T_9$ plants, with one-week intervals between applications. Irrigation used tap water, adhering to conventional fenugreek farming practices. For $T_1$ (control), granular urea (46% N) was applied at 0.75 g per pot during soil preparation and two weeks after sowing. Single superphosphate (15% $P_2O_5$) was added at 2.5 g per pot and mixed with urea during soil preparation. Potassium sulfate (50% $K_2O$) was applied at 1.25 g per pot.

## 2. Soil sampling and analysis

Soil samples were randomly collected from the soil mixture used in the main experiment before sowing during the 2020/2021 and 2021/2022 seasons. These samples were analyzed using Miller and Miller's (1987) method for physical properties and Dewis and Freitas' (1970) and Jackson's (1973) methods for chemical properties. The results are presented in Table 1.

**Table 1: Physical and chemical properties of the experimental soil mixture before sowing in both growing seasons.**

| Soil analysis | 2021/ 2022 | 2022/ 2023 |
|---|---|---|
| **Soil particles distribution %** | | |
| **Sand** | 60.00 | 57.12 |
| **Silt** | 25.22 | 27.02 |
| **Clay** | 14.78 | 15.86 |
| **Textural class** | Sandy loam | |
| **Soil pH** | 8.21 | 8.17 |
| **Ec (ds/m)** | 2.03 | 1.92 |
| **Organic Carbon (%)** | 0.71 | 0.65 |
| **Organic Matter (%)** | 1.22 | 1.13 |
| **Total $CaCO_3$ (%)** | 4.51 | 3.83 |
| **Available nutrients (mg $kg^{-1}$)** | | |
| **N** | 10.12 | 10.25 |
| **P** | 4.02 | 4.71 |
| **K** | 130 | 127 |
| **Soluble anions and cations (mg 100 $g^{-1}$)** | | |
| **$Cl^-$** | 69.03 | 65.41 |
| **$HCO_3^-$** | 22.14 | 15.33 |
| **$SO_4^{-2}$** | 63.58 | 68.64 |
| **$CO_3^{-2}$** | - | - |
| **$Mg^{+2}$** | 10.33 | 13.23 |
| **$Ca^{+2}$** | 102.25 | 96.56 |

## 3. Vermicompost and Vermitea

Vermicompost, sourced from a private farm in Alexandria, Egypt, was used to prepare vermitea. A 2 kg sample was converted into a liquid extract (vermitea) by steeping it in 4 liters of water for 72 hours under aerobic conditions (Edwards *et al.*, 2010). The vermitea was then sieved through a 2 mm mesh and diluted with water to prepare 10 L of a 20% solution. This solution was applied as a foliar spray, with three applications for $T_4$, $T_6$, and $T_8$ plants, and six applications for $T_5$, $T_7$, and $T_9$ plants.. Both vermicompost and vermitea were analyzed for pH, electrical conductivity (EC) (Jackson, 1973), hygroscopic water content, organic carbon (Dewis & Freitas, 1970), and organic matter content (Minasny *et al.*, 2020). Nutrient levels, including available nitrogen, phosphorus, and potassium, were determined using methods described by Horneck and Miller (1998), Olsen *et al.* (1954), and Hesse (1971), respectively. The results are presented in Tables 2 and 3.

**Table 2: Chemical composition of vermicompost.**

| pH | EC (ds/m) | Hygroscopic water (%) | Organic carbon (%) | Organic matter (%) | Available N (%) | Available P (%) | Available K (%) |
|---|---|---|---|---|---|---|---|
| 7.73 | 2.00 | 5.00 | 23.67 | 40.81 | 3. 52 | 0. 26 | 0.44 |

**Table 3: Chemical composition of vermitea.**

| pH | EC (ds/m) | Organic carbon (g $l^{-1}$) | Organic matter (g $l^{-1}$) | Available N (mg $l^{-1}$) | Available P (mg $l^{-1}$) | Available K (mg $l^{-1}$) |
|---|---|---|---|---|---|---|
| 7.25 | 0.89 | 2.93 | 5.05 | 120.12 | 23.74 | 62.00 |

## 4. Sampling and collecting data

### 4.1. Growth parameters

On the 70th day after sowing (DAS) in both growing seasons, four plants were randomly selected from each treatment for comprehensive growth evaluation. The assessments included the root system size ($cm^3$), plant height (cm), the number of branches and leaves, fresh and dry weights of roots, stems, and leaves (g), and total leaf area ($cm^2$) per plant. Root system size was measured following the method of Wanas (1996). The total leaf area ($cm^2$) per plant was calculated using the method described by Waidyanatha & Goonasekera (1975).

The plant's stems, leaves, and roots were separated, cleansed with deionized water, and dried at 70°C to a constant weight, recorded as dry weight. Dried leaves and stems were ground into a fine powder with a NIMA grinder (model BL-888A, Japan) and stored in paper sacks at 25°C until chemical analysis. The following growth indices were calculated using plant dry matter data:

a) The root/shoot ratio was calculated with the following equation:

$$Root/\ Shoot\ ratio = \frac{Root\ dry\ weight/Plant}{Shoot\ dry\ weight/Plant}$$

b) Leaf area ratio (LAR): calculates the leaf area ($cm^2$) formed per unit of plant dry biomass (g) using the formula of Radford (1967):

$$LAR\ (cm^2\ g^{-1}) = \frac{Total\ leaf\ area\ (cm^2)/Plant}{Plant\ dry\ weight}$$

### 4.2. Photosynthetic pigments

Chlorophyll a, chlorophyll b, and carotenoid concentrations were determined in the 4th apical leaf at 70 DAS in both seasons. Photosynthetic pigments were extracted using 80% acetone as described by Lichtenthaler (1987), and optical densities were measured at wavelengths 664, 647, and 480 nm using a Jenway PFP 7 spectrophotometer, following Wellburn (1994). Concentrations were expressed as mg $g^{-1}$ fresh weight (FW).

### 4.3. Chemical constituents

#### 4.3.1 Total carbohydrates and total phenols

Dry shoot samples collected at 70 DAS were analyzed using the methods of Dubois *et al.* (1956) for carbohydrates and Stabell *et al.* (1996) for phenols. Results were expressed as mg $g^{-1}$ DW.

#### 4.3.2. NPK and crude protein

Dry shoot powder samples (0.2 g each) collected at 70 DAS were digested with sulfuric and perchloric acids and diluted to 50 ml with distilled water (Nagornyy, 2013). Total nitrogen was determined by the micro Kjeldahl method (Horneck and Miller, 1998), and crude protein was calculated by multiplying total nitrogen by 6.25 (AOAC, 2023). Phosphorus was determined following Jackson (1973). Potassium was measured using a flame emission spectrophotometer (Jenway PFP 7) as described by Horneck and Hanson (1998). Concentrations were calculated as mg $g^{-1}$ DW.

## 5. Statistical Analysis

All data were analyzed using one-way ANOVA under a randomized complete block design in IBM SPSS Statistics (version 29.0.1.0). Treatment means were compared to the control using the LSD test ($P \le 0.05$) following Snedecor and Cochran (1989).

# RESULTS

## 1. Growth parameters

The results in Tables 4 and 5 show the effects of vermicompost as a soil application at rates of 60 g per pot ($VC_1$) and 120 g per pot ($VC_2$) and vermitea applied as a foliar spray three times ($VT_1$) and six times ($VT_2$), as well as their combinations ($VC_1$+$VT_1$, $VC_1$+$VT_2$, $VC_2$+$VT_1$, and $VC_2$+$VT_2$), on growth aspects of the fenugreek plant compared to control plants receiving 100% NPK fertilizer. Across both growing seasons, all treatments, both individual and combined, significantly improved the majority of growth parameters, including root size, root fresh and dry weights; stem length, branch and leaf numbers, total leaf area per plant, and shoot fresh and dry weight, when compared to the control (Fig. 1). In contrast, these treatments resulted in a significant reduction in the root/shoot ratio and leaf area ratio (LAR). The combination treatments showed a greater impact than individual applications, with $VC_2$+$VT_2$ having the greatest impact, followed by $VC_2$+$VT_1$, $VC_1$+$VT_2$, and $VC_1$+$VT_1$. In the first season, $VC_2$+$VT_2$ significantly enhanced growth ($P \leq 0.05$), with considerable increases of 163.47% in root size, 113.50% in root fresh weight, 130.55% in root dry weight, and 91.00% in stem length. It also improved branch number by 110.08%, leaf number by 29.28%, shoot fresh weight by 96.89%, and shoot dry weight by 194.83%, resulting in a 189.82% increase in total plant dry weight. However, the root/shoot ratio decreased by 25.00%. Similar patterns were observed during the second season, further validating the consistent efficacy of these treatments.

**vTable 4: Effect of vermicompost and vermitea treatments applied separately and in combination on some growth aspects of fenugreek plants at 70 DAS during the 2021/2022 season.**

| Parameters / Treatments | | Root parameters | | | Stem parameters | | Leaf parameters | | Shoot | | Root/ shoot ratio | Total plant DW (g) | LAR ($cm^2 g^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Size ($cm^3$) | FW (g) | DW (g) | Length (cm) | Branches No. | No. | Total area ($cm^2$) | FW (g) | DW (g) | | | |
| Control* | $\bar{X}$ | 5.23 i | 2.00 g | 0.36 f | 34.03 g | 4.76 g | 90.64 i | 1248.7 g | 33.51 g | 4.26 g | 0.08 ab | 4.62 g | 270.38 a |
| $VC_1$ | $\bar{X}$ | 7.17 f | 2.82 e | 0.53 e | 43.40 e | 6.63 e | 109.14 f | 1644.7 e | 42.68 e | 7.22 e | 0.07 bcd | 7.76 e | 212.04 de |
| | ± % | +37.09 | +41.00 | +47.22 | +27.53 | +39.29 | +20.41 | +31.79 | +27.36 | +69.48 | -12.50 | +67.97 | -21.58 |
| $VC_2$ | $\bar{X}$ | 12.17 c | 3.50 c | 0.68 bc | 52.86 c | 8.16 c | 114.57 c | 2758.2 b | 52.98 c | 10.33 c | 0.06 cd | 11.01 c | 250.66 b |
| | ± % | +132.70 | +75.00 | +88.89 | +55.33 | +71.43 | +26.40 | +120.89 | +58.10 | +142.49 | -25.00 | +138.31 | -7.29 |
| $VT_1$ | $\bar{X}$ | 6.47 h | 2.59 f | 0.51 e | 39.70 f | 5.90 f | 100.33 h | 1362.7 f | 38.88 f | 6.29 f | 0.08 ab | 6.80 f | 200.41 e |
| | ± % | +23.71 | +29.50 | +41.67 | +16.66 | +23.95 | +10.69 | +9.13 | +16.03 | +47.65 | 0.00 | +47.19 | -25.88 |
| $VT_2$ | $\bar{X}$ | 6.74 g | 2.53 f | 0.54 de | 39.76 f | 5.83 f | 102.15 g | 1628.2 e | 38.74 f | 6.26 f | 0.08 a | 6.80 f | 239.39 b |
| | ± % | +28.87 | +26.50 | +50.00 | +16.84 | +22.48 | +12.70 | +30.40 | +15.61 | +46.95 | 0.00 | +47.19 | -11.46 |
| $VC_1$ +$VT_1$ | $\bar{X}$ | 8.48 e | 3.16 d | 0.62 cd | 48.83 d | 7.30 d | 110.17 e | 1870.7 d | 48.64 d | 8.09 d | 0.07 abc | 8.71 d | 214.94 d |
| | ± % | +62.14 | +58.00 | +72.22 | +43.49 | +53.36 | +21.55 | +49.81 | +45.15 | +89.91 | -12.50 | +88.53 | -20.50 |
| $VC_1$ +$VT_2$ | $\bar{X}$ | 8.80 d | 3.55 c | 0.72 b | 52.90 c | 8.10 c | 111.24 d | 1959.9 c | 52.98 c | 10.36 c | 0.07 cd | 11.08 c | 176.88 f |
| | ± % | +68.26 | +77.5 | +100.00 | +55.45 | +70.17 | +22.73 | +56.96 | +58.10 | +143.19 | -12.50 | +139.83 | -34.58 |
| $VC_2$ +$VT_1$ | $\bar{X}$ | 12.56 b | 3.84 b | 0.73 b | 58.03 b | 9.03 b | 116.45 b | 2763.4 b | 59.21 b | 11.46 b | 0.06 d | 12.19 b | 226.77 c |
| | ± % | +140.15 | +92.00 | +102.78 | +70.53 | +89.71 | +28.48 | +121.30 | +76.69 | +169.01 | -25.00 | +163.85 | -16.13 |
| $VC_2$ +$VT_2$ | $\bar{X}$ | 13.78 a | 4.27 a | 0.83 a | 65.00 a | 10.00 a | 117.18 a | 2883.6 a | 65.98 a | 12.56 a | 0.06 cd | 13.39 a | 215.40 cd |
| | ± % | +163.47 | +113.5 | +130.55 | +91.00 | +110.08 | +29.28 | +130.92 | +96.89 | +194.83 | -25.00 | +189.82 | -20.33 |
| LSD at $p \leq 0.05$ | | 0.10 | 0.20 | 0.07 | 0.70 | 0.29 | 0.27 | 46.96 | 0.60 | 0.38 | 0.01 | 0.39 | 11.64 |

**The data represent the mean ($\bar{X}$) of four replicates (n=4). Values with different letters within every variant differ significantly (p<0.05), with percentage changes relative to the control (± %).**

**Abbreviations: Control*= Control with 100% of the recommended NPK fertilizers, $VC_1$ = Vermicompost at the rate of 60 g per pot, $VC_2$ = Vermicompost at the rate of 120 g per pot, $VT_1$ = Vermitea applied as foliar spray 3 times, $VT_2$ = Vermitea applied as foliar spray 6 times, DAS= Days after sowing, No. = Number, DW = Dry weight, FW = Fresh weight, LAR = Leaf area ratio.**

**Table 5: Effect of vermicompost and vermitea treatments applied separately and in combination on some growth aspects of fenugreek plants at 70 DAS during the 2022/2023 season.**

| Parameters | Root parameters | Stem parameters | Leaf parameters | Shoot | Root/ | Total | LAR ($cm^2 g^{-1}$ |
|---|---|---|---|---|---|---|---|

| Treatments | | Si ze ($cm^3$) | F W (g) | D W (g) | L ength (cm) | B ranches No. | No. | Total area ($cm^2$) | F W (g) | D W (g) | shoot ratio | plant DW (g) | $^{1})$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Co ntrol* | | 5.24 i | 1.58 g | 0.38 e | 36.30 g | 5.10 g | 91.28 i | 1349.4 g | 34.53 g | 5.00 g | 0.08 ab | 5.38 g | 250.82 a |
| $VC_1$ | | 7.25 f | 2.44 e | 0.54 d | 46.20 e | 7.23 e | 109.13 f | 1636.2 e | 43.70 e | 7.96 e | 0.07 bc | 8.50 e | 192.49 d |
| | % | +38.36 | +54.43 | +42.11 | +27.27 | +41.76 | +19.56 | +21.25 | +26.56 | +59.20 | -12.50 | +57.99 | -23.26 |
| $VC_2$ | | 12.19 c | 3.12 c | 0.71 bc | 56.76 c | 9.16 c | 115.24 c | 2578.1 c | 54.00 c | 11.06 c | 0.06 bc | 11.78 c | 218.85 bc |
| | % | +132.63 | +97.47 | +86.84 | +56.36 | +79.61 | +26.25 | +91.06 | +56.39 | +121.20 | -25.00 | +118.96 | -12.75 |
| $VT_1$ | | 6.44 h | 2.17 f | 0.53 d | 41.80 f | 6.16 f | 101.01 h | 1470.7 f | 39.90 f | 7.03 f | 0.08 ab | 7.56 f | 194.54 d |
| | % | +22.90 | +37.34 | +39.47 | +15.15 | +20.78 | +10.66 | +8.99 | +15.55 | +40.60 | 0.00 | +40.52 | -22.44 |
| $VT_2$ | | 6.75 g | 2.11 f | 0.56 d | 41.83 f | 6.23 f | 102.83 g | 1636.1 e | 39.76 f | 7.00 f | 0.08 a | 7.56 f | 216.41 c |
| | % | +28.81 | +33.54 | +47.37 | +15.23 | +22.16 | +12.65 | +21.25 | +15.15 | +40.00 | 0.00 | +40.52 | -13.72 |
| $VC_1+VT_1$ | | 8.47 e | 2.76 d | 0.65 c | 51.16 d | 8.16 d | 110.16 e | 1845.4 d | 49.66 d | 8.83 d | 0.07 ab | 9.48 d | 194.66 d |
| | % | +61.64 | +74.68 | +71.05 | +40.94 | +60.00 | +20.69 | +36.76 | +43.82 | +76.60 | -12.50 | +76.20 | -22.39 |
| $VC_1+VT_2$ | | 8.78 d | 3.14 c | 0.73 b | 56.63 c | 9.06 c | 111.56 d | 2559.9 c | 54.00 c | 11.10 c | 0.07 bc | 11.83 c | 216.39 c |
| | % | +67.56 | +98.73 | +92.11 | +56.01 | +77.65 | +22.22 | +89.71 | +56.39 | +122.00 | -12.50 | +119.89 | -13.73 |
| $VC_2+VT_1$ | | 12.56 b | 3.42 b | 0.73 bc | 63.33 b | 10.20 b | 117.43 b | 2858.3 b | 60.23 b | 12.20 b | 0.07 c | 12.93 b | 221.05 b |
| | % | +139.69 | +116.46 | +92.11 | +74.46 | +100.00 | +28.65 | +111.82 | +74.43 | +144.00 | -12.50 | +140.33 | -11.87 |
| $VC_2+VT_2$ | | 13.78 a | 3.87 a | 0.84 a | 70.23 a | 11.06 a | 118.21 a | 2967.9 a | 67.00 a | 13.30 a | 0.06 bc | 14.14 a | 209.89 cd |
| | % | +162.98 | +144.94 | +121.05 | +93.47 | +116.86 | +29.50 | +119.94 | +94.03 | +166.00 | -25.00 | +162.83 | -16.32 |
| LSD at $p \leq 0.05$ | | 0.07 | 0.22 | 0.08 | 0.40 | 0.47 | 0.70 | 63.20 | 0.60 | 0.38 | 0.012 | 0.37 | 15.83 |

**The data represent the mean ($\bar{X}$) of four replicates (n=4). Values with different letters within every variant differ significantly (p<0.05), with percentage changes relative to the control (± %).**

**Abbreviations: Control*= Control with 100% of the recommended NPK fertilizers, $VC_1$ = Vermicompost at the rate of 60 g per pot, $VC_2$ = Vermicompost at the rate of 120 g per pot, $VT_1$ = Vermitea applied as foliar spray 3 times, $VT_2$ = Vermitea applied as foliar spray 6 times, DAS= Days after sowing, No. = Number, DW = Dry weight, FW = Fresh weight, LAR = Leaf area ratio.**

## 2. Photosynthetic pigments

The results reveal statistically significant increases ($p \leq 0.05$) in chlorophyll a, chlorophyll b, total chlorophyll, and carotenoids with all individual treatments of vermicompost ($VC_1$ and $VC_2$) and vermitea ($VT_1$ and $VT_2$) as well as their combined treatments ($VC_1+VT_1$, $VC_1+VT_2$, $VC_2+VT_1$, $VC_2+VT_2$). Vermicompost applied as a soil amendment at 60 g per pot ($VC_1$) and 120 g per pot ($VC_2$) was more effective than vermitea applied foliarly three times ($VT_1$) and six times ($VT_2$), with $VC_2$ showing the highest efficacy (Fig. 2). However, integrative treatments outperformed the individual treatments, with $VC_2+VT_2$ being the most effective, followed by $VC_2+VT_1$, $VC_1+VT_2$, and $VC_1+VT_1$. The combined $VC_2+VT_2$ treatment produced the greatest relative increases over the control. In the first season, it raised chlorophyll "a" by 138.0%, chlorophyll "b" by 121.0%, total chlorophyll by 134.78%, and carotenoids by 120.0%. In the second season, the corresponding rises were 137.25%, 100.00%, 126.27%, and 128.57%, respectively (Fig. 2).

## 3. Chemical constituents

Tables 6 &7 display the mean values ($\bar{X}$) of total carbohydrates, crude protein, total phenols, nitrogen, phosphorus, and potassium concentrations (mg $g^{-1}$) in fenugreek shoots, alongside the percentage changes arising from the applied treatments compared to the control. Statistically significant increases ($p < 0.05$) in all assessed chemical constituents were obtained with both vermicompost treatments ($VC_1$ and $VC_2$) and vermitea treatments ($VT_1$ and $VT_2$), as well as with their combined applications ($VC_1+VT_1$, $VC_1+VT_2$, $VC_2+VT_1$, $VC_2+VT_2$) compared with the control group.

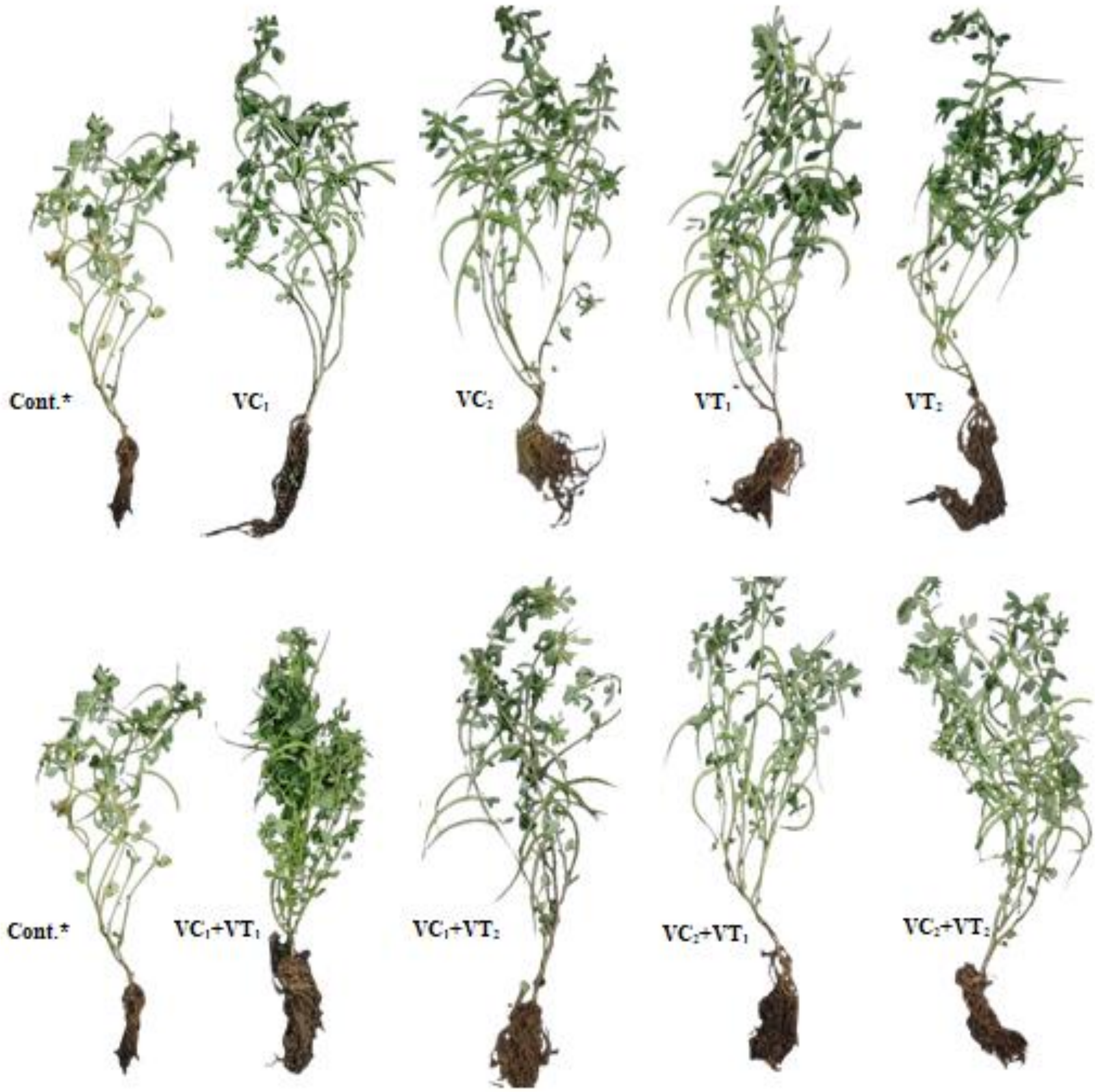


**Fig. 1: Shows positive effects of both vermicompost and vermitea applied separately and in combination on various morphological features of fenugreek at 70 DAS during the 2022/2023 season.**

**Abbreviations: Cont.*= Control with 100% of the recommended NPK fertilizers, $VC_1$ = Vermicompost at the rate of 60 g per pot, $VC_2$ = Vermicompost at the rate of 120 g per pot, $VT_1$ = Vermitea applied as foliar spray 3 times, $VT_2$ = Vermitea applied as foliar spray 6 times, DAS= Days after sowing.**

Specifically, when vermicompost was applied as a soil amendments, $VC_1$ (60 g per pot) and $VC_2$ (120

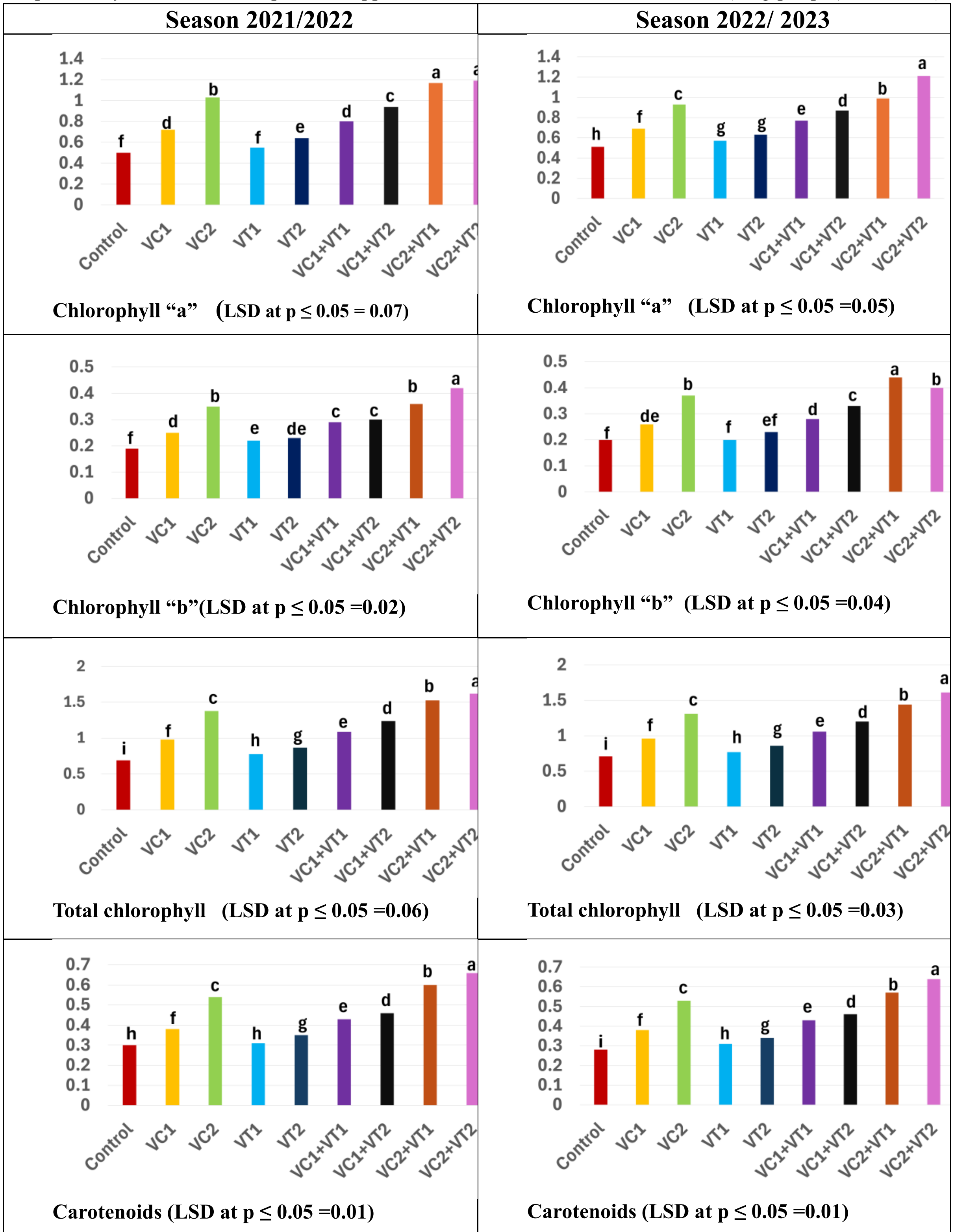


**Fig. 2: Effect of vermicompost and vermitea treatments applied separately and in combination on photosynthetic pigment concentrations (mg $g^{-1}$) in fenugreek leaves at 70 DAS during the 2021/2022 and 2022/2023 seasons.**

Abbreviations: VC1 = Vermicompost at the rate of 60 g per pot, VC2 = Vermicompost at the rate of 120 g per pot, VT1 = Vermitea applied as foliar spray 3 times, VT2 = Vermitea applied as foliar spray 6 times.

g per pot) outperformed foliar vermitea applications provided three times ($VT_1$) and six times ($VT_2$), with $VC_2$ exhibiting the best performance. The synergistic VC+VT combinations surpassed the single treatments, with $VC_2$+$VT_2$ being the most effective, followed, in order, by $VC_2$+$VT_1$, $VC_1$+$VT_2$, and $VC_1$+$VT_1$.

Seasonal comparisons indicate that, in the first season, the $VC_2$+$VT_2$ treatment outscored the control by 19.64 % for total carbohydrates, 35.56% for crude protein, 109.11% for total phenolics, 35.56% for nitrogen, 433.33% for phosphorus, and 34.85% for potassium. In the second season, the equivalent gains were 19.49%, 37.68%, 136.89%, 37.69%, 387.23%, and 29.74%, respectively.

**Table 6: Effect of vermicompost and vermitea treatments applied separately and in combination on certain bioconstituents and NPK concentrations in fenugreek shoots at 70 DAS during the 2021/2022 seasons.**

| Parameters / Treatments | | Bioconstituents (mg $g^{-1}$ DW) | | | Mineral nutrients (mg $g^{-1}$ DW) | | |
|---|---|---|---|---|---|---|---|
| | | Total carbohydrates | Crude protein | Total phenolics | N | P | K |
| Control | X̄ | 307.24 g | 223.19 e | 4.28 c | 35.71 e | 0.42 i | 18.28 g |
| $VC_1$ | X̄ | 338.54 de | 276.56 c | 5.48 bc | 44.25 c | 0.98 f | 20.32 e |
| | ± % | +10.19 | +23.91 | +24.04 | +23.91 | +133.33 | +11.16 |
| $VC_2$ | X̄ | 361.31 ab | 288.88 abc | 5.84 b | 46.22 abc | 1.66 c | 22.42 c |
| | ± % | +17.60 | +29.43 | +36.45 | +29.43 | +295.24 | +22.65 |
| $VT_1$ | X̄ | 326.47 f | 245.81 d | 5.16 bc | 39.33 d | 0.57 h | 19.30 f |
| | ± % | +4.26 | 10.13 | +20.56 | +10.14 | +35.71 | +5.58 |
| $VT_2$ | X̄ | 331.32 ef | 253.06 d | 5.28 bc | 40.65 d | 0.73 g | 20.24 e |
| | ± % | +7.84 | +13.38 | +23.36 | +13.83 | +73.81 | +10.72 |
| $VC_1$+$VT_1$ | X̄ | 344.45 cd | 282.31 bc | 5.49 bc | 45.17 bc | 1.18 e | 21.34 d |
| | ± % | +12.11 | +26.49 | +28.27 | +26.49 | 180.95 | +16.74 |
| $VC_1$+$VT_2$ | X̄ | 351.22 bc | 288.75 abc | 5.71 b | 46.20 abc | 1.32 d | 21.35 d |
| | ± % | +14.31 | +29.37 | +33.41 | +29.38 | +214.29 | +16.79 |
| $VC_2$+$VT_1$ | X̄ | 366.62 a | 294.75 ab | 8.89 a | 47.16 ab | 1.88 b | 23.55 b |
| | ± % | +19.33 | +32.06 | +107.71 | +32.06 | +347.62 | +28.83 |
| $VC_2$+$VT_2$ | X̄ | 367.57 a | 302.56 a | 8.95 a | 48.41 a | 2.24 a | 24.65 a |
| | ± % | +19.64 | +35.56 | +109.11 | +35.56 | +433.33 | +34.85 |
| LSD at $p \leq 0.05$ | | 10.31 | 16.02 | 1.35 | 2.62 | 0.06 | 0.04 |

**The data represent the mean (X̄) of four replicates (n=4). Values with different letters within every variant differ significantly ($p<0.05$), with percentage changes relative to the control (± %).**

**Abbreviations: Control*= Control with 100% of the recommended NPK fertilizers, $VC_1$ = Vermicompost at the rate of 60 g per pot, $VC_2$ = Vermicompost at the rate of 120 g per pot, $VT_1$ = Vermitea applied as foliar spray 3 times, $VT_2$ = Vermitea applied as foliar spray 6 times, DAS= Days after sowing, DW = Dry weight.**

**Table 7: Effect of vermicompost and vermitea treatments applied separately and in combination on certain bioconstituents and NPK concentrations in fenugreek shoots at 70 DAS during the 2022/2023 seasons.**

| Parameters / Treatments | | Bioconstituents ($mg\ g^{-1}$ DW) | | | Mineral nutrients ($mg\ g^{-1}$ DW) | | |
|---|---|---|---|---|---|---|---|
| | | Total carbohydrates | Crude protein | Total phenolics | N | P | K |
| Control* | X̄ | 307.04 g | 210.13 e | 3.47 c | 33.62 e | 0.47 i | 17.55 f |
| $VC_1$ | X̄ | 337.61 de | 263.44 c | 4.62 bc | 42.15 c | 1.03 f | 21.65 b |
| | ± % | +9.96 | +25.37 | +33.14 | +25.37 | +119.15 | +23.36 |
| $VC_2$ | X̄ | 362.21ab | 278.38 abc | 5.07 b | 44.54 abc | 1.71 c | 19.38 d |
| | ± % | +17.97 | +32.48 | +46.11 | +32.48 | +263.83 | +10.43 |
| $VT_1$ | X̄ | 325.84 f | 233.44 d | 4.33 bc | 37.35 d | 0.61 h | 18.22 e |
| | ± % | +6.12 | +11.09 | +24.78 | +11.09 | +29.79 | +3.82 |
| $VT_2$ | X̄ | 330.97 ef | 242.43 d | 4.48 bc | 38.79 d | 0.78 g | 19.26 d |
| | ± % | +7.79 | +15.37 | +29.11 | +15.38 | +65.96 | +9.74 |
| $VC_1+VT_1$ | X̄ | 345.22 cd | 269.46 bc | 4.72 bc | 43.11 bc | 1.23 e | 20.56 c |
| | ± % | +12.43 | +28.23 | +36.03 | +28.23 | +161.70 | +17.15 |
| $VC_1+VT_2$ | X̄ | 352.16 bc | 276.81abc | 4.88 b | 44.29 abc | 1.37 d | 20.63 c |
| | ± % | +14.70 | +31.73 | +40.63 | +31.74 | +191.49 | +17.55 |
| $VC_2+VT_1$ | X̄ | 366.54 a | 282.88 ab | 8.13 a | 45.26 ab | 1.93 b | 22.65 a |
| | ± % | +19.38 | +34.62 | +134.29 | +34.62 | +310.64 | +29.06 |
| $VC_2+VT_2$ | X̄ | 366.87 a | 289.31 a | 8.22 a | 46.29 a | 2. 29 a | 22.77 a |
| | ± % | +19.49 | +37.68 | +136.89 | +37.69 | +387.23 | +29.74 |
| LSD at $p \leq 0.05$ | | 10.31 | 15.94 | 1.30 | 2.55 | 0.07 | 0.32 |

**The data represent the mean (X̄) of four replicates (n=4). Values with different letters within every variant differ significantly ($p<0.05$), with percentage changes relative to the control (± %).**

**Abbreviations: Control*= Control with 100% of the recommended NPK fertilizers, $VC_1$ = Vermicompost at the rate of 60 g per pot, $VC_2$ = Vermicompost at the rate of 120 g per pot, $VT_1$ = Vermitea applied as foliar spray 3 times, $VT_2$ = Vermitea applied as foliar spray 6 times, DAS= Days after sowing, DW = Dry weight.**

## DISCUSSION

Given the rising global population and the urgent need for food security amidst threats to agricultural sustainability, expanding the cultivation of legumes like fenugreek has become increasingly important due to their benefits for soil health and human nutrition. This study aimed to investigate the potential of vermicompost (VC) and its extract (vermitea [VT]) applied separately and in combination to improve the growth and photosynthetic efficiency and shoot chemical constituents of fenugreek plants. The obtained results revealed that both vermicompost (VC) and vermitea treatments applied individually and in combination caused considerable increases in most studied growth parameters, including root parameters (size, fresh and dry weights), stem length, branch and leaf numbers, and total leaf area per plant, but decreased, however the root/shoot ratio and the leaf area ratio. These results are in conformity with those of Abou El-Goud (2020) using VC and VT on eggplant and Pushpa *et al*. (2022) and Al-Hadithi *et al.* (2023) using VC on fenugreek.

It is noteworthy that the applied treatments resulted in an increase in total plant dry biomass while decreasing the root/shoot ratio. This is crucial since it implies that more metabolites are allotted to the formation of new branches, which contribute significantly to the enhancement of both the quantity of leaves and total leaf area per plant, as well as a capacity to produce additional pods, resulting in a higher overall seed and straw output.

Vermicompost applications promote vigorous fenugreek growth by acting as an effective biofertilizer rich in moisture, minerals, organic matter, and beneficial microorganisms, and by supplying phytohormones (auxins, gibberellins, and cytokinins) produced through the elevated microbial activity in vermicompost. Vermicompost typically contains 32–66% moisture, which fosters a favorable milieu for advantageous microorganisms and thereby improves nutrient availability and soil health (Vuković *et al.,* 2021; Mohite *et al.,* 2024). The organic matter fraction aids in moisture retention, mitigates soil desiccation, and ensures a consistent water supply to plants during dry spells (Kauser & Khwairakpam, 2022; Dhiman, 2023).

Beneficial microorganisms present in vermicompost (e.g., *Actinomycetes, Trichoderma, Pseudomonas, Bacillus spp.*; nitrogen-fixing bacteria such as Azotobacter, Azospirillum, Nitrobacter, and Rhizobium; and phosphate-solubilizing bacteria) contribute to plant protection by suppressing pathogens, enhancing innate disease resistance, and increasing nutrient availability for uptake, thereby fostering a conducive environment for robust growth (Bellitürk *et al.,* 2017; Vambe *et al.,* 2023; Mohite *et al.,* 2024). Vermicompost also supports nutrient cycling through mineralization of organic matter, thereby releasing nutrients for plant use and sustaining soil fertility while reducing nutrient losses. It provides higher concentrations of macro- and micronutrients than many conventional organic fertilizers, including N, P, K, Ca, Mg, Fe, Zn, Mn, Cu, and B, which are essential for plant growth (Ratnasari *et al.,* 2023; Mohite *et al.,* 2024).

Collectively, these factors improve soil conditions to promote deeper and more extensive root proliferation, enabling fenugreek to access a larger soil volume and acquire greater water and nutrient resources. The enhanced nutrient availability supports increased synthesis of metabolites and their translocation to various tissues, culminating in improved vegetative growth and more developed reproductive structures (Lunagariya *et al.,* 2018).

Vermitea, a liquid extract derived from vermicompost, is known for its rich mineral nutrients, beneficial soil microorganisms, and humic and fulvic acids found in solid vermicompost, as well as phytohormones that are produced by high vermicompost microbial activity and leach into the vermitea during the extraction process. These constituents play a crucial role in promoting healthy plant growth (Edwards *et al.,* 2006).

The current study revealed that all VC and VT treatments enhanced photosynthetic pigment levels compared to the control, with the highest effectiveness observed with the $VC_2$+$VT_2$ combined treatment across two consecutive seasons, aligning with the findings of Abou El-Goud (2020) and Abdel Salam & Roshdy (2022).

The increment in photosynthetic pigment concentrations obtained by VC and VT treatments justifies the observed decrease in leaf area ratio (LAR) in Tables 5 and 6, signaling improved photosynthetic efficiency. The VC and VT treatments likely boost pigment concentrations due to their phytohormone richness (auxins, cytokinins, and gibberellins), which promote chlorophyll biosynthesis and help maintain its integrity, delaying senescence (Hwang *et al.,* 2012; Taiz *et al.,* 2014). These biofertilizers also supply key macronutrients and micronutrients, including N, Mg, and Fe, crucial for chlorophyll formation and function (Ratnasari *et al.,* 2023; Mohite *et al.,* 2024)

Nitrogen is a core component of chlorophyll (chlorophylls a and b contain four N atoms in the porphyrin ring). Adequate N supports porphyrin precursor synthesis (δ-aminolevulinic acid, porphobilinogen, uroporphyrinogen) and the chlorophyll backbone, and it modulates the rate of chlorophyll biosynthesis and the chlorophyll a/b ratio by affecting chlorophyll-binding proteins in the photosystems. Magnesium is the central metal in the chlorophyll porphyrin ring and is incorporated during biosynthesis; its availability can influence Mg-chelatase activity, a key step in chlorophyll formation. Iron is essential as well, supporting regulatory steps and plastid enzymes linked to electron transport and chlorophyll biosynthesis within the tetrapyrrole pathway. Moreover, adequate Fe reduces oxidative stress that can accelerate chlorophyll degradation, helping preserve pigment content and photosynthetic capacity (Marschner, 2012; Taiz *et al.,* 2014).

Our results also revealed the enhancing effect of VC and VT individual and combined treatments on the concentrations of total carbohydrates, proteins and phenolics along with NPK, consistent with the findings of Bellitürk *et al.* (2017), who used vermicompost on peppers and eggplants; Abou El-Goud (2020), who used vermicompost and vermitea on eggplants; and Al-Sadek *et al.* (2024), who used vermicompost on tuberose.

Vermicompost and vermitea applications may enhance total carbohydrate content by improving photosynthetic efficiency, as indicated by elevated pigment levels (Table 7) and a reduced leaf area ratio (LAR), defined as leaf area in $cm^2$ formed per gram of dry matter (Tables 5 and 6). Consequently, greater production of fundamental substrates (hexoses) is available to fuel energy generation and diverse metabolic pathways, including the synthesis of amino acids, proteins, fatty acids, lipids, and secondary metabolites such as phenolic substances (Wanas 2018; Wanas *et al.,* 2025). Phenolic compounds contribute to improved nutrient mobility and signaling between roots and shoots (Sharma *et al.,* 2019) and enhance nutrient uptake by chelating metallic ions, thereby increasing the number of active absorption sites and facilitating the transportation of essential elements such as Ca, Mg, K, Zn, Fe, and Mn (Seneviratne & Jayasingheerachchi, 2003). Furthermore, vermicompost improves nutrient cycling by decomposing organic waste, allowing for the slow release of nutrients for plant use while minimizing nutrient losses and ensuring optimal long-term nutritional status. It also contains macro- and micronutrients (N, P, K, Ca, Mg, Zn, Fe, Mn, Cu, and B), as well as beneficial microorganisms, such as those assisting in phosphorus solubilization and nitrogen fixation (Ratnasari *et al.,* 2023; Mohite *et al.,* 2024). As a result, soil environment amendments encourage deeper and more extensive root growth, allowing plants to explore an expanded area of soil and absorb more water and nutrients. This increased nutritional availability promotes greater synthesis of metabolites and their distribution to various plant organs, resulting in improved vegetative growth and the development of reproductive structures (Lunagariya *et al.,* 2018).

## CONCLUSION

Vermicompost and its liquid extract (vermitea) are environmentally benign, sustainable biofertilizers that can be used in combination to improve soil qualities as well as food crop growth and productivity. Both biofertilizers, particularly when used in combination, successfully increased fenugreek growth, photosynthetic efficacy, and nutrient uptake, potentially leading to higher biological and economic yields.


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## CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest

## AUTHORS CONTRIBUTION

Wanas, A.L.; Abou El-Goud and Badr A.A. developed the concept of the manuscript. Wanas wrote the manuscript. All authors checked and confirmed the final revised manuscript.

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## الملخص العربى

### تأثيرات الفيرمى كمبوست وشاى الفيرمى على النمو والأداء الفسيولوجى لنبات الحلبة

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**1. قسم النبات الزراعى – كلية الزراعة – جامعة دمياط – مصر**

الفيرمى كمبوست هو سماد عضوى صديق للبيئة غني بالعناصر الغذائية والهرمونات النباتية والكائنات الحية المفيدة، يُحسّن خصائص التربة ونمو المحاصيل وإنتاجيتها. تناولت هذه الدراسة تأثير معاملات الفيرمى كمبوست وشاى الفيرمى كمبوست على نمو نبات الحلبة وخصائصه الفسيولوجية مقارنةً بنباتات الكنترول التي تلقت 100% من الأحتياجات السمادية من النيتروجين والفوسفور والبوتاسيوم الموصى بها. تضمنت المعاملات التجريبية الفيرمى كمبوست كمُحسِّن للتربة بجرعتين 60 جم و 120 جم ($VC_2$) لكل أصيص، شاى الفيرمى كمبوست كرش ورقي يُرش ثلاث مرات أو ست مرات أثناء النمو. كما تم تقييم جميع التفاعلات الممكنة بين هذه المعاملات الفردية كمعاملات تكاملية. اتبعت التجربة تصميم القطاعات كاملة العشوائية بتسعة معاملات وأربع مكررات. أظهرت النتائج المتحصل عليها تحسنًا ملحوظًا في كل معايير النمو المدروسة، وصبغات البناء الضوئى، والمكونات الكيميائية للمجموع الخضرى، حيث تفوقت المعاملات المشتركة للفيرمى كمبوست مع شاى الفيرمى كمبوست على المعاملات الفردية لكل منهما. وقد حققت المعاملة المشتركة (فيرمى كمبوست بمعدل 120 جم للأصيص مع الرش بشاى الفيرمى كمبوست 6 مرات أعلى نسبة زيادة عن الكنترول في حجم الجذور (163.47%)، وطول الساق (91.00%)، وعدد الفروع (110.08%)، وعدد الأوراق (29.28%)، وإجمالي مساحة الأوراق (130.92%)، والوزن الجاف (189.82%)، والكلوروفيل (134.78%)، والكربوهيدرات (19.64%)، والبروتينات (35.65%)، والفينولات (109.11%) في الموسم الأول، مع نتائج مماثلة في الموسم الثاني. تشير هذه النتائج إلى أن التطبيقات المتكاملة لـ لفيرمى كمبوست مع شاى الفيرمى كمبوست تُعدّ نهجًا فعالًا وصديقًا للبيئة لتعزيز نمو الحلبة وإنتاجيتها المستدامة، والذى قد يُفيد المحاصيل الأخرى أيضًا.