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# Evaluation of the combined impact of bio and organic fertilizers on some morphological characteristics, chemical composition and productivity of the henna plant, as well as the number of microorganisms in the soil rhizosphere.

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**Abstract:** A field experiment was conducted on clay soil in Armanet section, Aluxor Government, Egypt during two seasons (2021/2022) to study the effects of using plant growth promoting rhizobacteria (PGPR) and different types of bacterial strains as biofertilizers. The experiment also tested the use of compost tea or vermicompost tea as organic foliar extracts. **The results** showed that the combination of PGPR, compost, and organic teas led to higher growth and yield of henna plants compared to traditional mineral fertilizers. The bio-organic fertilizers also had a positive effect on the microoranisms in the soil. **Conclusions**, using bio-organic fertilizers can improve henna plant productivity and reduce the need for mineral fertilizers, benefiting the environment.

**Keywords:** Henna, plant growth promoting rhizobacteria (PGPR), Biofertilizer, vermicompost tea, compost tea, rhizospheric microorganisms.

## Introduction

The study of aromatic and medicinal plants has been extensively researched in recent years. There is a resurgence in the use of herbs in pharmaceuticals and cosmetics, with over 20,000 plant species now being used for their medicinal properties. Additionally, more than 80% of the world's population utilizes these plants (Padma, 2005 and Sarma et al., 2016). Henna, scientifically known as Lawsonia inermis Linn, is a member of the Lythereaceae family and is primarily found in subtropical and tropical regions. It is believed to have originated in Africa and Asia, with distribution in countries such as Egypt, Somalia, Sudan, India, Pakistan, and Sri Lanka (Chaudhary et al., 2010). The leaves of henna (Lawsonia inermis L.) have been used for centuries as a cosmetic dye, commonly applied to nails, hands, hair, and textiles. It is also utilized in the treatment of skin problems, hand aches, and other medical conditions (Zumrutdel et al., 2012).

The leaves of Lawsoina inermis contain phenolic and flavonoids as phytochemicals (Sharma et al., 2016).

PGPR are a diverse group of microorganisms that can promote plant growth. Recognizing the potential benefits of PGPR can lead to increased crop productivity. Using PGPR as biofertilizers can replace chemical fertilizers and pesticides, resulting in increased plant growth and yield (Glick, 1995 & (Kloepper et al., 2004 and Farzana et al., 2009.

Several reports show that PGPR has promoted the growth of cereals, vegetables, and medicinal aromatic plants. Biofertilizers are important for sustainable agricultural practices. Organic fertilizers like compost and vermicompost, as well as their teas, can meet the nutrient requirements of crops. The application of compost and its teas has a significant impact on plant growth, productivity, and soil properties (Kamilova, 2009; Mishra et al., 2010; Verma et al., 2010; Egamberdieva, 2011; Mansour et al., 2011; Houssein and Abotaleb, 2023).

The primary aims of this study were to examine the function of plant growth promoting rhizobacteria (PGPR) in conjunction with various types and concentrations of compost, along with organic extract teas, as organic fertilizers in order to enhance henna productivity and increase the overall abundance of microorganisms in the rhizosphere. Additionally, the goal was to reduce dependence on synthetic fertilizers and mitigate environmental pollution.

## MATERIALS AND METHODS

A field experiment was conducted on clay soil at our farm, specifically in the Arment section of Aluxor Government, located at a latitude of 32° 60' 31" N and a longitude of 037° 25' 32.5333" E. This experiment took place in Egypt over the course of two consecutive seasons (2021/2022) in order to assess the combined impact of bio and organic fertilizers on various growth and productivity parameters of henna plants, as well as the overall abundance of soil rhizospheric microorganisms.

1. **Soil**:

The soil samples were subjected to analysis in order to determine their mechanical, physical, and chemical properties, as outlined by Jackson (1973) and documented in Table (1).

2. **Host plant:**

Hardwood cuttings, with a length ranging from 25 to 30 cm and containing 6 to 9 nodes of the local henna cultivar (Lawsonia inermis L.) were utilized in this research. These cuttings were graciously acquired from a private farm located in the Aswan governorate of Upper Egypt.

3. **Fertilizers used:**

a. **Mineral fertilizers:**

Synonyms: Nitrogen mineral (N), phosphorus (P), and potassium (K) manure were implemented at the two levels the first level at the recommended doses (60 N, 30 P, and 48 K) forms 300kg ammonium sulfate (20.5% N), 200kg super phosphate (15.5% P2O5) and 100kg potassium sulfate (48% K2O) per Fadden, the second level was25% N, P, and K from the recommended doses waterlogging involves executing drainage systems, enhancing soil structure, selecting suitable crops, and practicing effective water management. By deploying these tactics, land managers can alleviate waterlogging issues, promote proper soil drainage, and ensure optimal conditions for plant growth. This ultimately contributes to upholding agricultural productivity and sustainability in waterlogged areas.

**Table 1 Mechanical and chemical properties of soil.**

| **Property** | **Before planting** |
|---|---|
| **Soil particle size distribution** | |
| Sand (%) | 9.93 |
| Silt (%) | 19.27 |
| Clay (%) | 70.80 |
| Texture | Clay |
| **Chemical analysis** | |
| pH (in soil paste) | 8.20 |
| E.C (ds/m) | 0.63 |
| Saturation percentage (%) (SP) | 43.70 |
| Organic matter (%) | 0.74 |
| Available N (ppm) | 40 |
| Available P (ppm) | 6.2 |
| Available K (ppm) | 310 |
| **Soluble cations and anions (meqL$^{-1}$)** | |
| $Ca^{++}$ | 2.70 |
| $Mg^{++}$ | 1.20 |
| $Na^{+}$ | 2.40 |
| $K^{+}$ | 0.10 |
| $CO^{--}_3$ | 0.0 |
| $HCo_3^{-}$ | 2.80 |
| $Cl^{-}$ | 1.20 |
| $SO^{--}_4$ | 2.40 |
| **Available amounts (mg Kg$^{-1}$) of some nutrients** | |
| Fe | 320 |
| Zn | 120 |
| Mn | 150 |
| Cu | 0.10 |

**b. Organic fertilizer used:**

- **Compost:**

Plant organic matter that consisted of plant remains with exclusively microbial decomposition was utilized and administered at the two magnitudes of 8 and 2 tons per Fadden. Certain chemical characteristics of the organic matter utilized can be found in Table (2) as indicated by Page et al. (1982).

**Table 2. Some physical and chemical properties of organic fertilizer used (compost) during this study.**

| Analysis | Values |
|---|---|
| **Bulk density (kg $M^3$)** | 686 |
| **Moisture content%** | 28.5 |
| **pH** | 7.6 |
| **EC ($dsm^2$)** | 4.82 |
| **Organic matter %** | 51.73 |
| **Organic carbon %** | 30.07 |
| **Ash %** | 71.5 |
| **Total nitrogen %** | 1.70 |
| **C/N ratio** | 1:17.9 |
| **Total P** | 0.8 |
| **Total K** | 1.3 |
| **Fe ppm** | 1250 |
| **Zn ppm** | 1.8 |
| **Mn ppm** | 3.60 |
| **Cu ppm** | 105 |
| **Nematoda** | Nil |
| **Seed weed** | Nil |
| ***E.coli*** | Nil |

- **Organic teas;**

Compost and vermicompost infusions were generated obtained from expedited infusion as biological deterioration of plant remains identical operative microorganisms and/or association between earthworms (1:10 water) and implemented as a foliar infusion at the two levels (5 and 10 liters per fed-1) at two intervals 30 and 60 days after sowing (AP). Certain chemical characteristics of the two varieties of organic infusions exploited are exhibited in Table (3) corresponding to Page et al. (1982).

**Table 3. Some physical and chemical properties of organic fertilizer used (compost) during this study.**

| Properties | Values | |
|---|---|---|
| | Compost tea | Vermicompost tea |
| pH | 8.35 | 8.72 |
| EC (dsm$^2$) | 2.95 | 3.21 |
| Available N- ($NH_4$) ppm | 8.75 | 11.70 |
| Available N- ($NO_3$) ppm | 25.31 | 37.81 |
| Total nitrogen ppm | 791 | 863 |
| Total phosphors ppm | 11200 | 14300 |
| Total potassium ppm | 14750 | 15893 |
| Fe ppm | 15.63 | 21.73 |
| Zn ppm | 7.67 | 9.83 |
| Mn ppm | 3.17 | 4.25 |
| Cu ppm | 1.51 | 1.83 |

**c. Biofertilizer (PGPR):**

Three distinct categories of bacterial strains were employed as biofertilizers and/or plant growth-promoting rhizobacteria (PGPR). These strains include 1) Azotobacter chroococcum and Azospirillum brasilense, which function as diazotrophic bacteria capable of fixing nitrogen as free and associative organisms. They are used in combination as a mixed culture, known as Azoto + Azo (1:1). 2) Bacillus megaterium (Bm) serves as a phosphate dissolving bacteria (PDB). Lastly, 3) Bacillus circulans (Bc) is utilized as a potassium releasing bacteria (KRB). The bacterial cultures were generously procured from the biofertilizers production unit (BPU) at the Agriculture Microbiology Department of the Soil Water and Environment Research Institute (SWERI), which is part of the Agricultural Research Center (ARC) in Giza, Egypt. During the planting of henna plants, the hardwood cuttings were inoculated by soaking them in mixed liquid cultures

(1N:1P:1K) derived from the aforementioned three strains (Azoto+Azo) + Bm + Bc. The bacterial load in the inoculant was maintained at a level below 109cfuml-1. Furthermore, a basal dressing of the aforementioned inocula was re-applied 21 days after planting and utilized as a foliar application at a dosage of 10 liters per Fadden.

## 4. Field experiment

The experiment was conducted using a randomized complete block design (RCBD) with three replicates. Each plot had an area of 10.5 m2 (3x3.5) or 1/400 fed-1. The following treatments were applied:

T1: Control (no treatment).

T2: Full recommended dose of N, P, and K mineral fertilizers.

T3: Organic fertilizer (compost) at a rate of 8 tons per feddan.

T4: Compost (2 tons per feddan) + 25% of the recommended N, P, and K mineral fertilizers + PGPR.

T5: T4 + compost tea at a rate of 5 liters per feddan (applied 30 days after sowing).

T6: T4 + compost tea at a rate of 5 liters per feddan (applied 90 days after sowing).

T7: T4 + compost tea at a rate of 10 liters per feddan (applied 30 days after sowing).

T8: T4 + compost tea at a rate of 10 liters per feddan (applied 90 days after sowing).

T9: T4 + vermicompost tea at a rate of 5 liters per feddan (applied 30 days after sowing).

T10: T4 + vermicompost tea at a rate of 5 liters per feddan (applied 90 days after sowing).

T11: T4 + vermicompost tea at a rate of 10 liters per feddan (applied 30 days after sowing).

T12: T4 + vermicompost tea at a rate of 10 liters per feddan (applied 90 days after sowing).

**5. Plant determination**

Two cuts at the growth stage (180 and 360 DAP) five henna plants were uprooted from each plot to assay the following parameters plant height (cm), number of branches, area as well as fresh and dry weight of leaves per plant, and yield of dry weight of leaves per plot (kg plot-1) and yield of dry leaves ton per Fadden (ton fed-1), according to A.O.A.C.(2005).

**6. Measurements of plant leaf phytochemical of henna plants**

Both total phenolic content (TPC) and total flavonoids content (TFC) were determined according to (Cheng *et al*., 2007) and Pothitirat *et al*., 2009.

**7. Microbial determination**

The quantification of rhizospheric microorganisms, including total bacteria (cfu 106), fungi (cfu 104), and actinomyces (cfu 105), per unit of dry soil (g) was determined prior to planting (time zero) as well as after the first and second cuts, referred to as cut one and cut two, using the methodologies established by Page et al. (1982).

**8. Statistical analyses**

The outcomes were executed through the utilization of analyses of variance, specifically ANOVA. The least significant differences (L.S.D.) were computed from the ANOVA tables, following the methodology established by Steel and Torrie (1984).

## RESULTS AND DISCUSSION

### 1. Growth characteristics of henna plants:

The growth characteristics of henna plants, such as plant height (cm), number of branches (no. $plant^{-1}$), and leaf area ($mm^2$), were analyzed after 180 and 360 DAP (cut 1 and cut 2) and are presented in Table (4). The data obtained from the experiment revealed that the combined application of PGPR as biofertilizers and compost as organic fertilizers, along with foliar application of compost tea or vermicompost tea at two different rates (5 and 10 l. $Fed^{-1}$) and two different times, resulted in significant differences and notable increases in all tested henna plants compared to the untreated control. Additionally, the treatment that received biofertilizers + 2-ton compost as organic fertilizer + 1/3 N mineral fertilizer dose exhibited higher values, with no significant differences observed compared to the treatment that received the recommended N, P, and K mineral fertilizers or 8-ton compost per Fadden as organic fertilizers. Among the tested treatments, the treatment that received the higher rate (10 l.fed-1) of foliar application of vermicompost tea + 1/3 N mineral fertilizers + 2-ton compost $fed^{-1}$ in combination with PGPR as biofertilizers demonstrated the highest values for plant height (218.2 cm), number of branches (35 $plant^{-1}$), and leaf area (45.8 mm2) compared to the other treatments in both tested cuts.

**Table (4): The height (cm), Number of branches(no plant$^{-1}$), and Leaf area (mm$^2$)of Henna plants as affected by the application of different fertilizer treatments at 180 and 360 DAP**

| | Plant height (cm) | | | Number of branches (no plant$^{-1}$) | | | Leaf area (mm$^2$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | cut 1 | cut 2 | mean | cut 1 | cut 2 | mean | cut 1 | cut 2 | mean |
| **Control (1)** | 92.7 | 95.6 | 94.0 | 14 | 15 | 14.5 | 25.1 | 24.8 | 24.9 |
| **F.N (2)** | 161.0 | 173.2 | 167.1 | 25 | 27 | 26.0 | 34.2 | 36.7 | 35.5 |
| **F.O.M (3)** | 153.0 | 162.8 | 157.9 | 16 | 20 | 18.0 | 37.7 | 39.2 | 38.5 |
| **Bio+ F.O.M+1/3N (4)** | 162.7 | 166.3 | 164.5 | 20 | 25 | 22.5 | 32.7 | 34.8 | 33.8 |
| **(4)+5LCT$_1$** | 179.3 | 183.2 | 181.3 | 23 | 28 | 25.5 | 36.2 | 42.7 | 39.5 |
| **(4)+5LCT$_2$** | 192.7 | 197.5 | 195.1 | 23 | 31 | 27.0 | 39.6 | 44.8 | 42.2 |
| **(4)+10CT$_1$** | 183.2 | 187.4 | 185.2 | 25 | 33 | 29.0 | 37.3 | 39.2 | 38.3 |
| **(4)+10CT$_2$** | 201.0 | 209.3 | 205.2 | 21 | 37 | 29.0 | 31.5 | 34.3 | 32.9 |
| **(4)+5LVT$_1$** | 192.3 | 201.7 | 197.0 | 28 | 28 | 28.0 | 36.2 | 40.2 | 38.2 |
| **(4)+5LVT$_2$** | 200.7 | 210.8 | 205.8 | 24 | 32 | 28.0 | 37.4 | 41.7 | 39.6 |
| **(4)+10LVT$_1$** | 205.7 | 215.3 | 210.5 | 28 | 29 | 28.5 | 37.7 | 43.7 | 40.7 |
| **(4)+10LVT$_2$** | 206.0 | 218.4 | 212.2 | 28 | 35 | 31.5 | 39.6 | 45.8 | 42.7 |
| **L.S.D. 0.05** | 5.63 | 6.23 | 7.91 | 4.25 | 6.65 | 7.27 | 2.88 | 3.17 | 4.03 |

The findings from the experiment displayed data on the fresh weight (g plant-1) and dry weight (g plant-1) of leaves, as well as the weight in kilograms per plot (kg plot$^{-1}$) and kilograms per feddan (kg fed$^{-1}$). The analysis of the data in Table (5) indicated that the plants treated with a combination of bio and organic fertilizers, along with 1/3 N mineral fertilizers and foliar application at two different rates and times, exhibited higher values and significant increases in both the fresh and dry weight of henna leaves. In comparison to the treatment receiving either the recommended doses of N, P, and K mineral fertilizers or the full dose of organic fertilizer (8-ton fed$^{-1}$), Treatment (T4) demonstrated higher values for the fresh and dry weight of henna leaves. Furthermore, the application of foliar organic teas, such as compost and vermicompost teas, at the two rates and times resulted in higher values and significant differences compared to the other tested treatments. The treatment that received bio and organic fertilizers + 1/3 N mineral fertilizers dose + vermicompost tea at a rate of 10 l.fed-1 at cut 2 exhibited the highest values for fresh weight (341.7 g plant-1), dry weight (159.7 g plant$^{-1}$), weight per plot (6.388 kg plot$^{-1}$), and weight per feddan (2559.6 kg fed$^{-1}$) when compared to the other tested treatments.

**Table (5): Fresh weight of leaves, dry weight of leaves of Henna plants as affected by the application of different fertilizer treatments at 180 and 360 DAP.**

| | Fresh weight of leaves (g. plant$^{-1}$) | | | Dry weight of leaves (g. plant$^{-1}$) | | | Dry weight of leaves (kg plot$^{-1}$) | | | Dry weight of leaves (kg fed$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cut 1 | cut 2 | mean | cut 1 | cut 2 | mean | cut 1 | cut 2 | mean | cut 1 | cut 2 | mean |
| **Control (1)** | 27.0 | 28.3 | 27.7 | 14.7 | 15.3 | 15.0 | 0.588 | 0.612 | 0.600 | 235.2 | 244.8 | 240.0 |
| **F.N (2)** | 148.0 | 163.7 | 155.9 | 70.7 | 75.7 | 73.2 | 2.828 | 3.028 | 2.928 | 1131.2 | 1211.2 | 1171.2 |
| **F.O.M (3)** | 85.3 | 92.1 | 88.7 | 39.5 | 49.3 | 44.4 | 1.580 | 1.972 | 1.776 | 632.0 | 788.8 | 710.4 |
| **Bio+ F.O.M+1/3N (4)** | 189.7 | 193.4 | 191.6 | 88.9 | 92.7 | 90.8 | 3.556 | 3.708 | 3.632 | 1422.4 | 1483.2 | 1452.8 |
| **(4)+5LCT$_1$** | 178.0 | 183.2 | 180.6 | 85.8 | 87.4 | 86.6 | 3.432 | 3.496 | 3.464 | 3172.8 | 1398.4 | 1385.6 |
| **(4)+5LCT$_2$** | 226.3 | 245.2 | 235.8 | 110.7 | 118.3 | 114.5 | 4.428 | 4.732 | 4.580 | 1770.2 | 1892.8 | 1832.0 |
| **(4)+10CT$_1$** | 253.3 | 278.9 | 266.1 | 112.6 | 131.7 | 122.2 | 4.504 | 5.268 | 4.88 | 1801.6 | 2107.2 | 1955.2 |
| **(4)+10CT$_2$** | 262.0 | 294.1 | 278.1 | 127.1 | 142.8 | 134.9 | 5.084 | 5.712 | 5.396 | 2033.6 | 2284.8 | 2158.4 |
| **(4)+5LVT$_1$** | 261.7 | 287.3 | 274.5 | 139.2 | 139.2 | 139.2 | 5.568 | 5.568 | 5.568 | 2227.2 | 2227.2 | 2227.2 |
| **(4)+5LVT$_2$** | 283.7 | 305.7 | 294.7 | 144.3 | 147.2 | 145.8 | 5.772 | 5.88 | 5.808 | 2308.8 | 2355.2 | 2323.2 |
| **(4)+10LVT$_1$** | 292.0 | 325.1 | 308.6 | 154.4 | 151.7 | 153.1 | 6.176 | 6.068 | 6.124 | 2470.4 | 2435.2 | 2449.6 |
| **(4)+10LVT$_2$** | 300.0 | 341.7 | 320.9 | 156.4 | 159.7 | 158.1 | 6.256 | 6.388 | 6.324 | 2502.4 | 2555.2 | 2559.6 |
| **L.S.D. 0.05** | 25.63 | 43.72 | 46.23 | 15.81 | 19.17 | 23.32 | 1.054 | 1.278 | 1.554 | 381.6 | 417.2 | 597.6 |

Irrespective of the utilization of the two types of organic foliar teas, namely compost and vermicompost, at the two different rates of 5 and 10 liters per feeding, and at two distinct time points of 0 and 60 days after planting, in conjunction with both bio and organic fertilizers, along with a 1/3 dose of N mineral fertilizer, as well as the two cuts that were examined, the data presented in Table 6 demonstrated that the application of both organic teas in the presence of bio and organic fertilizers, combined with a 1/3 dose of N mineral fertilizer, resulted in a percentage range of 12 to 112%, 6 to 90%, 3 to 55, and 45 to 779 for plant height (in centimeters per plant), number of branches (per plant), leaf area (in square millimeters), and leaf dry weight (in kilograms per feeding), respectively, in comparison to the control treatment. The control treatment consisted of the application of the recommended doses of N, P, and K mineral fertilizers, an organic fertilizer (at a rate of 8 tons per feeding), and biofertilizers in combination with a 2-ton compost per feeding and a 1/3 dose of N mineral fertilizers, in the aforementioned order.

**Table (6): The effect of applications of both compost and vermicompost teas on some vegetative growth parameters (plant height, number of branches, leaf area and leaves fresh and dry weight) of henna plants as an average of the two tested cuts.**

| | **Plant height (cm)** | | **Number of branches (no plant$^{-1}$)** | | **Leaf area (mm$^2$)** | | **Dry weight of leaves (kg fed$^{-1}$)** | |
|---|---|---|---|---|---|---|---|---|
| | **value** | **%** | **value** | **%** | **value** | **%** | **value** | **%** |
| **Control** | 94.0 | 112 | 14.5 | 90 | 24.9 | 55 | 240.0 | 779 |
| **FN** | 167.1 | 19 | 26 | 6 | 35.5 | 9 | 1171.2 | 80 |
| **F.O.M.** | 157.9 | 26 | 18.0 | 53 | 38.5 | 3 | 710.4 | 197 |
| **Bio+F.O.M+1/3N** | 164.5 | 21 | 22.5 | 22 | 33.8 | 14 | 1452.8 | 45 |
| **Bio+F.O.M+1/3N+O. teas** | 199.5 | - | 27.6 | - | 38.6 | - | 2111.4 | - |

This phenomenon may be attributed to the fundamental rate of PGPR as biofertilizers and compost as organic fertilizers, as well as their co-application with the foliar organic two teas, which contribute to the enhancement of henna plant growth by augmenting both soil fertility and soil rhizospheric microorganisms. In this regard, the findings obtained are consistent with the reports of Attia-Elham (2000), Attia-Elham and Hoda (2005), Abo El Ala (2015), El Massoudi et al. (2019), and Ibrahim et al. (2022), who observed that applying PGPR in various forms and microbial types in conjunction with diverse sources and levels of organic fertilizers and organic foliar components (such as organic acids or teas extract), together with reduced amounts of N, P, and K fertilizers, resulted in notable enhancement of both growth characteristics and yield productivity of henna plants. Moreover, these practices yielded significant differences when compared to the application of mineral N, P, and K fertilizers alone, particularly under different soil types, stress conditions, and circumstances.

**2. Both total phenolic content (TPC) and total flavonoids content (TFC) as leaf phytochemical compounds of henna plant**

The data obtained from the two cuts, as well as the average of the two cuts, revealed that the application of various fertilized treatments had a significant impact and led to significant increases in both total phenolic content (TPC) and total flavonoid content (TFC). Furthermore, when henna plants were inoculated with PGPR as biofertilizers, combined with compost as an organic fertilizer and 1/3 N mineral fertilizer dose, in the presence of compost tea or vermicompost teas, higher values for the two tested parameters were observed compared to other treatments. The values recorded at cut2 and in the presence of vermicompost were higher than those at cut1 and the other fertilized treatments. Specifically, the values ranged from 0.78 to 1.98 and 1.07 to 2.11 for TPC at cut1 and cut2, respectively, and the corresponding values for TFC were 0.70 to 1.96

and 0.81 to 2.53, respectively. The data obtained from table (8) indicated that the application of two types of organic foliar compounds (compost or vermicompost teas) combined with PGPR, organic fertilizers, and 1/3 N mineral fertilizer dose supported the stimulation of higher amounts of TPC and TFC in henna plant leaves compared to other fertilized treatments. This resulted in a higher percentage increase of up to 103% for TPC and 163% for TFC compared to other fertilized treatments. These findings are consistent with previous studies by Kasntin et al. (2013), Abo El-Ela (2015), Al Damy et al. (2016), and Leela and Sing (2020), which reported that henna plant leaves exhibit significant physicochemical properties (TPC and TFC) and show higher values when various fertilized systems, such as mineral fertilizers, organic fertilizers, and PGPR as biofertilizers, are applied individually or in combination with organic foliar compounds, such as organic acids and/or extract teas.

**Table (7): Total phenols ($g^{-1}$ 100g) and Total flavonoids ($g^{-1}$ 100g) of Henna plants leaves as affected by application of different fertilized treatments at 180 DAP**

| | Total phenols ($g^{-1}$ 100g) | | | Total flavonoids ($g^{-1}$ 100g) | | |
|---|---|---|---|---|---|---|
| | cut 1 | cut 2 | mean | cut 1 | cut 2 | mean |
| **Control (1)** | 1.05 | 1.15 | 1.10 | 0.77 | 0.81 | 0.79 |
| **F.N (2)** | 1.43 | 1.48 | 1.46 | 0.70 | 0.76 | 0.73 |
| **F.O.M (3)** | 0.78 | 1.07 | 0.93 | 0.96 | 1.11 | 1.04 |
| **Bio+ F.O.M+1/3N (4)** | 1.86 | 1.93 | 1.90 | 0.92 | 1.08 | 1.00 |
| **(4)+5LCT$_1$** | 1.92 | 1.98 | 1.95 | 0.93 | 1.10 | 1.02 |
| **(4)+5LCT$_2$** | 1.52 | 1.95 | 1.74 | 1.42 | 1.63 | 1.52 |
| **(4)+10CT$_1$** | 1.42 | 1.46 | 1.44 | 1.87 | 1.98 | 1.93 |
| **(4)+10CT$_2$** | 1.88 | 1.93 | 1.91 | 1.89 | 2.11 | 2.00 |
| **(4)+5LVT$_1$** | 1.96 | 2.03 | 2.00 | 1.93 | 2.43 | 2.18 |
| **(4)+5LVT$_2$** | 1.93 | 1.98 | 1.96 | 1.96 | 2.53 | 2.25 |
| **(4)+10LVT$_1$** | 1.98 | 2.11 | 2.05 | 1.94 | 2.47 | 2.21 |
| **(4)+10LVT$_2$** | 1.95 | 2.05 | 2.00 | 1.96 | 2.51 | 2.24 |
| **L.S.D. 0.05** | 0.21 | 0.28 | 0.33 | 0.11 | 0.31 | 0.28 |

**Table (8): The effect of applications of both compost and vermicompost teas on Total phenols ($g^{-1}$ 100g) and Total flavonoids ($g^{-1}$ 100g) of henna leaves plants as an average of the two tested cuts.**

| | **Total phenols** | | **Total flavonoids** | |
|---|---|---|---|---|
| | TPC | % | TFC | % |
| **Control (1)** | 1.10 | 72 | 0.79 | 143 |
| **F.N (2)** | 1.46 | 29 | 0.73 | 163 |
| **F.O.M (3)** | 0.93 | 103 | 1.04 | 85 |
| **Bio+F.O.M+1/3N+O. teas** | **1.89** | **-** | **0.92** | **-** |

### 3. Rhizosphric microorganisms of henna plants total count of bacteria, fungi, and actinomycetes:

The findings of the comprehensive enumeration of bacteria (colony-forming units ≈ 10^6), fungi (colony-forming units ≈ 10^4), and actinomycetes (colony-forming units ≈ 10^5) in the rhizosphere of planted henna plants, as influenced by different fertilizer treatments, can be found in Table (9). The collected data revealed that the experimental site exhibited lower values for total bacteria (2.12 x 10^6), fungi (1.06 x 10^4), and actinomycetes (1.82 x 10^5) before the planting process. However, when henna plants were planted as is or fertilized with recommended amounts of nitrogen (N), phosphorus (P), and potassium (K) mineral fertilizers, higher values were observed in comparison to the aforementioned pre-planting values, with no statistically significant differences observed. The application of organic fertilizers alone or in combination with biofertilizers, along with the presence of organic foliar components such as compost and vermicompost teas, resulted in even higher values and significant increases compared to the untreated treatments at the tested time points (180 and 360 days after planting). The treatment that received plant growth-promoting rhizobacteria (PGPR) as biofertilizer, compost as organic fertilizer, and one-third of the recommended amount of N mineral fertilizer, along with foliar application of vermicompost tea at a rate of 10 liters per feddan, twice, exhibited the highest values for total bacteria (14.72 x 10^6), fungi (9.67 x 10^4), and actinomycetes (11.41 x 10^5).

**Table (9): Total count of bacteria (-x$10^6$), total count of Fungi (-x$10^4$) and total count of actinomycetes (-x$10^5$) of the rhizosphere of Henna plants as affected by the application of different fertilizer treatments at 180 DAP.**

| | Total count of bacteria (-x$10^6$) | | | Total count of Fungi (-x$10^4$) | | | Total count of Actinomycetes (-x$10^5$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | cut 1 | cut 2 | mean | cut 1 | cut 2 | mean | cut 1 | cut 2 | mean |
| **Before planting** | **2.12** | | | **1.06** | | | **1.82** | | |
| **Control (1)** | 2.18 | 4.53 | 3.36 | 1.01 | 1.21 | 1.11 | 2.07 | 3.71 | 2.89 |
| **F.N (2)** | 3.80 | 6.37 | 5.09 | 1.09 | 1.19 | 1.14 | 3.66 | 4.66 | 4.16 |
| **F.O.M (3)** | 5.47 | 8.31 | 6.89 | 2.09 | 2.19 | 2.14 | 4.96 | 5.31 | 5.14 |
| **Bio+ F.O.M+1/3N (4)** | 6.32 | 9.43 | 7.88 | 3.58 | 3.85 | 3.72 | 6.70 | 7.25 | 6.98 |
| **(4)+5LCT$_1$** | 6.81 | 10.11 | 8.46 | 5.02 | 6.31 | 5.67 | 5.57 | 7.57 | 6.57 |
| **(4)+5LCT$_2$** | 7.76 | 11.72 | 9.74 | 4.95 | 7.04 | 5.99 | 8.08 | 9.11 | 8.60 |
| **(4)+10CT$_1$** | 8.76 | 12.33 | 10.55 | 5.04 | 7.73 | 6.39 | 8.75 | 9.93 | 9.34 |
| **(4)+10CT$_2$** | 9.99 | 12.78 | 11.39 | 5.73 | 8.11 | 6.92 | 8.99 | 9.98 | 9.49 |
| **(4)+5LVT$_1$** | 7.82 | 12.88 | 10.35 | 4.83 | 8.17 | 6.28 | 9.04 | 10.04 | 9.54 |
| **(4)+5LVT$_2$** | 8.71 | 13.11 | 10.91 | 6.11 | 9.02 | 7.57 | 9.28 | 10.83 | 10.01 |
| **(4)+10LVT$_1$** | 9.43 | 13.20 | 11.32 | 6.22 | 9.31 | 7.77 | 10.01 | 11.22 | 10.62 |
| **(4)+10LVT$_2$** | 11.32 | 14.72 | 13.02 | 6.62 | 9.67 | 8.15 | 10.14 | 11.41 | 10.91 |
| **L.S.D. 0.05** | 1.62 | 2.73 | 2.90 | 1.55 | 2.17 | 2.48 | 2.27 | 3.14 | 3.61 |

Furthermore, the data presented in Table (9) indicates that the treatments not subjected to compost tea or vermicompost tea exhibited lower values for total bacteria, fungi, and actinomycetes. However, the application of either compost tea or vermicompost tea resulted in significant percentage increases ranging from 34% to 214%, 84% to 717%, and 23% to 214% for total bacteria, fungi, and actinomycetes counts, respectively, compared to the control treatment. This increase was observed in the presence of recommended doses of N, P, and K mineral fertilizers, compost as organic fertilizer (8-ton fed$^{-1}$), and PGPR as biofertilizers, along with 2-ton compost fed-1 and 1/3 mineral fertilizer dose, in the same order. These findings are consistent with the results reported by Ragab et al. (2006), El-Mehrat et al. (2013), Elmaghraby et al. (2011), and Zaky (2019), which suggest that the application of biofertilizers (PGPR) and organic fertilizer in various sources, levels, and forms, in conjunction with low amounts of N, P, and K mineral fertilizers, can activate and positively impact rhizosphere soil microorganisms in different types of cultivated crops. This leads to an increase in the number and count of these microorganisms by up to 620% during the growth stage period, compared to untreated and uninoculated treatments.

**Table (10): The effect of the applications of both compost and vermicompost teas on the total counts of the microbial rhizosphere of henna plants as an average of the two tested cuts.**

| | Total count of bacteria (-x10$^6$) | | Total count of Fungi (-x10$^4$) | | Total count of Actinomycetes (-x10$^5$) | |
|---|---|---|---|---|---|---|
| | **count** | **%** | **count** | **%** | **count** | **%** |
| **Before planting** | **2.12** | **-** | **1.06** | **-** | **1.82** | **-** |
| **Control (1)** | 3.36 | 214 | 1.11 | 717 | 2.89 | 214 |
| **F.N (2)** | 5.09 | 107 | 1.14 | 501 | 4.16 | 118 |
| **F.O.M (3)** | 6.89 | 53 | 2.14 | 207 | 5.14 | 76 |
| **Bio+ F.O.M+1/3N (4)** | 7.88 | 34 | 3.72 | 84 | 6.98 | 23 |
| **Bio+F.O.M+1/3N+O. teas** | **10.55** | **-** | **6.85** | **-** | **9.07** | **-** |

## CONCLUSION

There is a substantial body of evidence indicating that the utilization of PGPR as biofertilizers, when combined with various types, levels, and forms of organic fertilizers, along with reduced quantities of mineral N, P, and K fertilizers, holds significant promise as a viable approach to enhance both growth and yield productivity. Additionally, this approach has the potential to diminish the reliance on chemical agricultural components for medicinal and aromatic plants, thereby fostering the development of environmentally sustainable agriculture. Furthermore, it is plausible to assert that such a fertilization regimen may function as a sound agricultural practice, not only serving to augment henna plant productivity, but also effectively curbing reliance on chemical fertilizers and mitigating environmental pollution.

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