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RESEARCH ARTICLE

Influence of Vermicompost Derived from Rice Straw, Neem Leaves, and Cow Dung on Plant Growth Parameters of *Solanum lycopersicum* (Tomato)

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Abstract

Objectives: To investigate the effect of vermicompost derived from different combinations of rice straw, cow dung, and neem leaves on growth and productivity of tomato plants (*Solanum lycopersicum*). **Methods:** The vermicomposting studies are performed with rice straw, cow dung, and neem leaves in plastic containers under ambient conditions using *Eisenia fetida* species of earthworm. The vermicomposts (A, B, and C) are used with soil to evaluate influence on growth and productivity of tomato plants as compared with compost, commercial organic fertilizer, and control, i.e. T1: soil + vermicompost A, T2: soil + vermicompost B, T3: soil + vermicompost C, T4: soil + compost, T5: soil + commercial organic fertilizer, and T6: only soil (control). **Findings:** The vermicompost (C) produced with the highest stock density (40) of *Eisenia fetida* showed maximum improvement in growth parameters and productivity of tomato plants (T3), i.e. 6.13, 11.2, 1.14, 2.82, 3.65, 0.30, 15.3 fold, and 7.58% increase in mean leaf number, plant height, stem diameter, plant weight, root weight and length, tomato number, and weight, respectively. There is found positive correlation between physicochemical parameters of the vermicompost and productivity of tomato plants. The vermicompost showed the best growth and productivity in tomato plants as compared with commercial organic fertilizer, compost, and control. **Novelty:** The present study is performed under cool and humid climate of Gurugram from October 2021 to January 2022. Neem leaves improved nutritional quality of vermicompost at same stock density of *Eisenia fetida*.

Keywords: Earthworm; Eisenia fetida; Rice straw; Tomato plant; Vermicompost; Compost

1 Introduction

The agricultural sector is crucial to achieve sustainable development by ensuring food security and environmental protection. The rice is a staple food for many countries around the world. The rice demand is projected to increase by 28% by 2050 due to the growing population globally[1]. The Asian region accounts for approximately 90.5% of the world's rice production (Food and Agricultural Organization)[2]. India ranks 2^{nd} in terms of rice and wheat production in the world. The rice and wheat production increased from 109.52 million tons in 2020 to 122.27 million tons in 2021[3]. The rice straw production has also increased proportionately with the increase in the rice production. The rice straw (stalk of rice) is an agricultural by-product which is left in the field after harvesting of rice grains. The rice and wheat together represent about 70% of the total crop residue (500 Million tons) produced annually in India[4]. A major fraction of the crop residue is commonly burnt by the farmers to prepare the field for the next crop. This practice not only deteriorates the soil and air quality but also adversely affect the human health and the environment. The crop residue burning also results in loss of nutrients from the soil, i.e. carbon, silicon, nitrogen (100%), phosphorus (25%), potassium (20%), and sulphur (5-60%)[5].

The rice straw is considered one of the most important agricultural wastes for scalable applications. The vermicomposting is a sustainable technology for effective management of the rice straw. It is an easier, cost-effective, and ecofriendly approach for the decomposition of the organic wastes by combined action of earthworms and microorganisms to produce a valuable soil like material (vermicompost). The vermicompost consists of hormones and plant growth regulators which have been reported to positively influence the growth of legumes, vegetables, cereals, and ornamental plants etc. The beneficial effects on the plant growth reached to a maximum when the vermicompost accounted for about 30-50% of the soil volume[6]. The present study attempted incorporation of 25% vermicompost in soil to evaluate influence on the growth and productivity of the tomato plants. Various species of earthworms have been employed for conversion of a diverse range of organic wastes into vermicompost. *Eisenia fetida* species of earthworm is selected for the present study because of prolific breeding, voracious feeding habit, 1–3 years of longevity, survival under aberrant weather conditions, and easy handling.

The composted material should get completely stabilized before use as a fertilizer to prevent negative effects on the growth of plants due to oxygen depletion and nitrogen mineralization. Hence, the present study involved 30 days of pre-decomposition and 90 days of vermicomposting to ensure complete stabilization of the vermicompost. The most of the previous studies focused on comparing influence of the vermicompost on plant growth parameters as compared with the control soil. However, we have additionally studied influence of the vermicompost on growth and productivity of the tomato plants in comparison with the commercial organic fertilizer and compost. Tomato plant requires high amount of nitrogen and other nutrients for proper growth and development. Hence, it is a good choice for determining nutrients supplying potential of the vermicompost for suitable growth of the plants. This study aimed to examine the influence of vermicomposts derived from different combinations of rice straw, cow dung, and neem leaves (*Azadirachta indica*) on growth and yield of the tomato plant.

2 Methodology

2.1 Vermicomposting

The rice straw was collected from the nearby agricultural fields at Gurugram, Haryana, India. The earthworms (*Eisenia fetida*) were procured from a vermicompost plant situated at Shikohpur, Gurugram, Haryana, India. Neem leaves were collected from road-side neem plants (*Azadirachta indica*). Cow dung was obtained from a cow shed situated at Gurugram, Haryana, India. The vermicomposting studies were performed in the plastic containers of 2 L capacity and 32 cm × 28 cm × 28 cm dimension under ambient conditions. The vermicompost and compost (control) samples were produced using air dried rice straw (fragments of 1-2 cm), cow dung (decomposed), neem leaves (container B only), and earthworm in different proportions (Figure 1). The vermibeds were prepared using cow dung as a bulking agent and soil. Rice straw, cow dung, and soil were added to all containers in 4:2:1 ratio, respectively. The feedstock was moistened regularly with distilled water to ensure sufficient moisture (80%) and pre-decomposed for 30 days to stabilize feedstock and provide suitable environment for the growth of earthworms. The earthworms were introduced into the vermibeds on 31^{st} day. The stock density of the earthworms was varied in different containers and the feedstock was subjected to vermicomposting for a period of 90 days. The feedstock was mixed manually on regular basis to ensure sufficient aeration and respiration. All the experiments were conducted in triplicate under shade at ambient conditions.

The feedstock, vermicompost, and compost (control) samples were characterized in terms of the various parameters, i.e. bulk density, moisture content, electrical conductivity (Conductivity Meter, Chemito, 130), total nitrogen (TN), total organic carbon (TOC), potassium (K), and calcium (Ca) (Flame Photometer, Beckman Model DU), C:N ratio, phosphate (P), and heavy metals (Atomic Absorption Spectrophotometer), for assessment of physicochemical changes as per standard methods (BOFFO 1985).

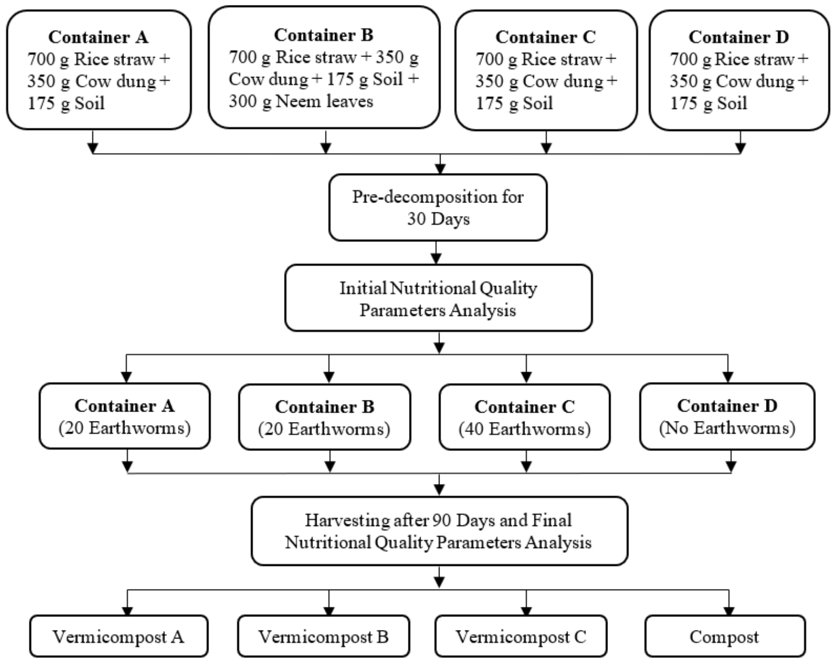

Fig 1. Vermicomposting experimental setup

2.2 Plant Studies

The vermicompost (A, B, and C), compost, and market available organic fertilizer (Fresh Essentials) were used with soil to evaluate influence on the growth and productivity of the tomato plants (*Solanum lycopersicum*) under ambient conditions. The experimental setup comprised of six different treatments (T1, T2, T3, T4, T5, and T6) in pots of dimension 32 cm × 28 cm × 28 cm as mentioned below:

T1: Soil (4.5 Kg) + Vermicompost A (1.5 Kg)
T2: Soil (4.5 Kg) + Vermicompost B (1.5 Kg)
T3: Soil (4.5 Kg) + Vermicompost C (1.5 Kg)
T4: Soil (4.5 Kg) + Compost (1.5 Kg)
T5: Soil (4.5 Kg) + Commercial Organic fertilizer (1.5 Kg)
T6: Only soil (control) (6 Kg)

One month and 6 days old tomato seedlings were collected from Welcome Nursery, Gurugram, Haryana, India. One seedling was planted in each pot (Figure 2 a). The initial growth parameters of the tomato seedlings, i.e. leaf number, plant height, and stem diameter, were measured. The leaf number was counted manually. The plant height was measured using scale from the soil line up to the tip of the plants main stem and the stem diameter was measured using Vernier caliper. The plants were watered regularly as per requirements. All growth parameters were measured after every 15 days, starting from transplantation of the seedlings to 60^{th} day. The number of tomatoes was counted manually after 30 days of flowering (Figure 2 b). The weight of the tomatoes is measured after 50 days of flowering using a weighing balance. The various growth parameters of the tomato plants, i.e. leaf number, stem height, stem diameter, number (productivity), and weight of the tomatoes were compared within the treatments. The plants were harvested after 120 days of transplantation and the mean wet plant weight, wet root weight, and root length were measured.

2.3 Statistical analysis

All the experiments were performed in triplicate. The sample mean is reported along with the standard error. The data sets are analyzed for variance using one way ANOVA followed by Tukey's all pair wise multiple comparison test using SPSS software (version 23) to determine differences between the treatments ($p < 0.05$). Pearson correlation analysis is also conducted between the vermicompost and compost physicochemical parameters and productivity of the tomato plants in Microsoft Excel 2013.

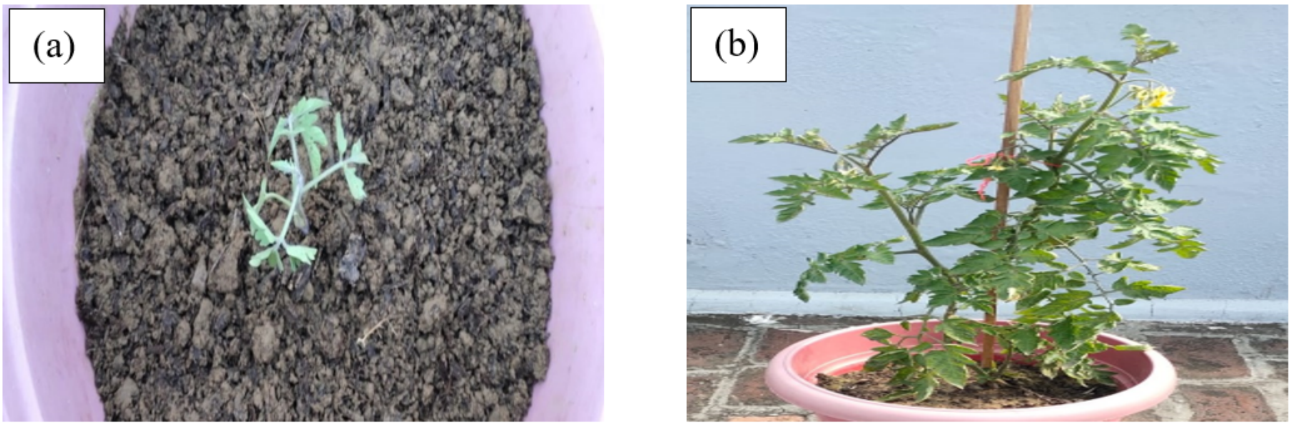

Fig 2. (a) Tomato seedlings transplantation in pots and (b) Flowering in tomato plant

3 Results and Discussion

The nutritional physicochemical characteristics of different vermicompost (A, B, and C) and compost samples (D) produced using rice straw, cow dung, and neem leaves are summarized in Table 1. The vermicompost C, produced with the highest stock density of the earthworms, showed the maximum improvement in the nutritional physicochemical characteristics as compared with vermicompost A, B, and compost. This may be attributed to the presence of sufficient growth hormones (ethylene, auxins, and gibberellins etc.) and enzymes (cellulose, nitrogenase, and phosphatase etc.) in the vermicast[7]. The addition of neem leaves is found to have positive influence on the nutritional parameters like nitrogen, organic carbon, Ca, P, and K in case of the vermicompost B as compared with the vermicompost A at same stock density of the earthworms.

Table 1. The Physicochemical characteristics of vermicompost and compost samples

Parameters	Vermicompost A	Vermicompost B	Vermicompost C	Compost
TN (%)	2.02 ± 0.003 a	2.11 ± 0.003 b	2.11 ± 0.00 b	1.3 ±0.00 d
P (%)	1.87 ± 0.00 c	2.09 ± 0.00 b	2.15 ± 0.009 a	1.28 ± 0.007 d
TOC (%)	16.22 ± 0.00 a	18.32 ± 0.003 b	14.32 ± 0.00 c	17.64 ± 0.003 d
Moisture content (%)	80.39 ± 0.137 a	80.52 ± 0.003 a	80.51 ± 0.000 a	80.33 ± 0.177 a
Bulk density (g/cm^3)	0.75 ± 0.003 b	0.74 ± 0.003 c	0.65 ± 0.00 d	0.79 ± 0.003 a
C:N ratio	8.03 ± 0.013 c	8.67 ± 0.013 b	6.79 ± 0.00 d	12.60 ± 0.003 a
K (%)	2.72 ± 0.009 c	3.05 ± 0.003 b	3.11 ± 0.007 a	2.35 ± 0.006 d
Conductivity (ms/cm)	1.11 ± 0.003 b	1.11 ± 0.003 b	1.21 ± 0.00 a	0.88 ± 0.007 c
Ca (%)	2.90 ± 0.003 c	3.10 ± 0.003 b	3.50 ± 0.003 a	2.15 ± 0.003 d
Mn	<0.05 mg/kg	<0.05 mg/kg	<0.05 mg/kg	<0.05 mg/kg
Fe	<0.01 mg/kg	<0.01 mg/kg	<0.01 mg/kg	<0.01 mg/kg
Cu	<0.05 mg/kg	<0.05 mg/kg	<0.05 mg/kg	<0.05 mg/kg
Zn	<0.01 mg/kg	<0.01 mg/kg	<0.01 mg/kg	<0.01 mg/kg

Parameter values in each row followed by different letters are significantly different $p < 0.05$.
One way ANOVA followed by post hoc Tukey's all pair wise multiple comparison test

Table 2. Regression equations between tomato productivity, vermicompost, and compost physicochemical parameters

Vermicompost Parameters	Tomato Productivity (Number)	P
TN	y = 0.0909x + 0.7864R^2 = 0.3392	0.047*
P	y = 0.1042x + 0.5901R^2 = 0.437	0.019*
TOC	y = -0.5635x + 23.432R^2 = 0.6435	0.0017**
Bulk density	y = -0.0215x + 0.993R^2 = 0.7952	0.00010**
K	y = 0.0943x + 1.666R^2 = 0.4624	0.015*
Ca	y = 0.1756x + 0.7921R^2 = 0.6133	0.0026**

**, * Significant at the 0.01 and 0.05 probability levels, respectively.

3.1 Influence of vermicompost on mean leaf number and mean stem diameter

The mean leaf number after 60 days is noted to be maximum for T3 (157 leaves) and minimum for T6 (47 leaves). There is observed 6.13 fold increase in mean leaf number for T3 which is followed by T2 (5.83 folds), T1 (5 folds), T5 (4.95 folds), T4 (4.69 folds), and T6 (2.39 folds) as compared with the initial values. The soil and vermicompost mixture illustrated better results as compared to the mixture of soil with compost, organic fertilizer, and control (Figure 3). The stock density of the earthworms is a decisive factor to influence the nutritional quality of the vermicompost which resulted in increased mean leaf number in the tomato plants. This might be due to the production of a finely fractionated humic organic matter with essential nutrients such as ammonium and nitrate that can be readily used by the plants [7]. On comparing results of treatment T1 with T2 (both having vermicompost produced with same stock density of the earthworm), it is concluded that neem leaves derived vermicompost (B) significantly increased the mean leaf number because of the rich nutritional quality (TOC, TN, P, K, and Ca) of the neem leaves. The commercial organic fertilizer in T5 showed better results than T4 (compost). Bziouech and co-workers (2022) [8] studied the effect of vermicompost and compost on cultivation of tomato plants and reported highest increase in the tomato plant leaves in pots with the vermicompost as compared to the control. Khomami and co-workers (2021) [9] reported taller Dracaena, Spathiphyllum, and Aglonema plants with increased nutrients content, fresh and dry leaf weight with 25% vermicompost than non-treated control. There is also reported increase in the leaf area, photosynthetic pigments, rate of respiration, and photosynthesis in tomato and brinjal plants with the application of fly ash vermicompost [10]. The better growth could be correlated with increase in the nutritional parameters of the vermicompost.

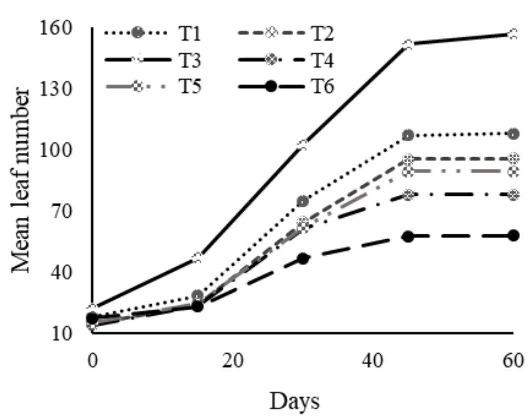

Fig 3. Comparison of mean leaf number in different treatments

The mean stem diameter increased to the maximum extent for T3 (1.14 folds) which is followed by T5 (0.53 folds), T1 (0.5 folds), T2 (0.45 folds), T4 (0.35 folds), and T6 treatments (0.29 folds) (Figure 5). The treatments T1 and T2 does not show any significant difference. The treatment with the commercial organic fertilizer (T5) showed better results as compared to T1 and T2. The similar positive influence of the application of vermicompost has also been reported in the previous studies. The stem thickness is reported to increase with the application of vermicompost with vermiwash as compared to only vermicompost and control treatments [11]. Ravindrana et al. (2019) [12] reported 8.9% increase in the stem girth with the use of tannery waste animal fleshing vermicompost. It is argued that production of the metabolites during vermicomposting leads to promotion of the microflora growth and hence have hormone like action on the plant growth parameters[13].

3.2 Influence of vermicompost on mean plant height and weight

The vermicompost amended treatments depicted significant increase in the mean plant height as compared to the control (Figure 4). The maximum increase is observed for T3 whereas minimum in case of T6 (control). There is observed 11.2 folds increase in the mean plant height for T3 which is followed by T2 (6.59 folds), T1 (6.16 folds), T5 (5.87 folds), T4 (3.75 folds), and T6 (2.06 folds). The organic fertilizer in T5 has shown same results as that of T1. The vermicompost derived with the neem leaves has not shown any significant influence on the mean plant height. The above findings are in good agreement with the existing literature. Awadhpersad et al. (2021)[11] found significant increase in the height and branches of the tomato plants with the vermicompost and vermiwash treatments as compared to the control. The stem cutting of sugarcane and mint plants showed higher shoot length and overall plant growth with the application of the vermicompost water extract[14]. The higher plant growth may be because of the presence of plant growth hormones like auxins, cytokinins, GA, and humic acid in the vermicompost.

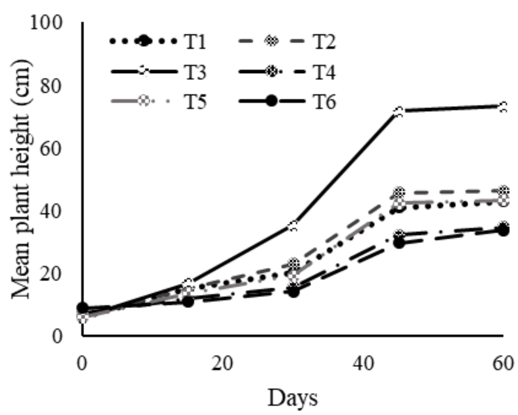

Fig 4. Comparisonof mean plant height in different treatments

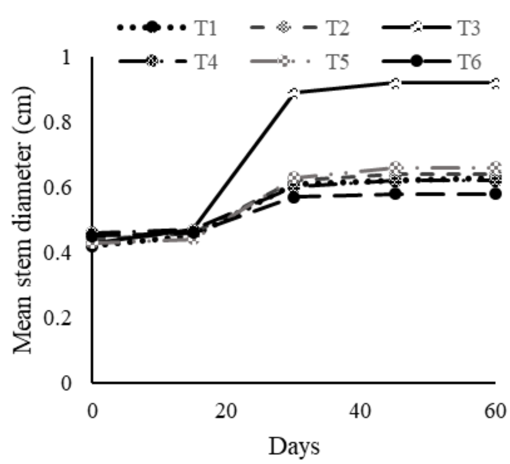

Fig 5. Comparison of mean stem diameter in different treatments

Treatment T3 showed maximum increase (2.82 fold) in the mean wet plant weight which is followed by T1 (2.03 folds), T2 (1.96 folds), T5 (1.85 folds), and T4 (0.14 fold) as compared to the control (T6). Vermicomposting produces macro- and micronutrients, hormones, growth stimulants, regulators, and enzymes (lipases, chitinases, amylases, proteases, and cellulase) that convert organic matter into plant accessible form [7].

3.3 Influence of vermicompost on mean root length and weight

The mean wet root weight is also recorded to be the highest in case of T3 (3.65 folds) which is followed by T2 (1.23 folds), T1 (1.06 folds), T5 (1.04 folds), and T4 (0.08 folds) as compared to the control. The treatments amended with vermicompost are found to have better mean root weight as compared to the compost and the control. However, there is not observed any significant difference in the results of treatments amended with the commercial organic fertilizer and the vermicompost. The maximum increase (0.30 fold) in the mean root length is achieved for T3 which is followed by 0.19, 0.16, and 0.04 fold increase for T1 and T5, T2, and T4, respectively, as compared to the control. Kumar et al. (2022) [15] reported higher nitrogen and phosphorus content in the neem leaves and cow dung vermicompost. However, in the present study, neem leaves derived vermicompost has not shown any significant effect on wet root weight, and root length (Figure 8).

3.4 Influence of vermicompost on mean tomato number and weight

The mean tomato number is identified to be the maximum in case of T3 and minimum for T6 (Figure 7). There is achieved 15.3 fold increase in the mean tomato number for T3 which is followed by T1 (11.7), T2 (11.3), T5 (11), T4 (10), and T6 (7.7). The stock density of the earthworms during vermicomposting is found to play an important role to increase the productivity of the tomato plants. Staffen et al. (2019) [16] reported increase in the fresh mass of the tomato and productivity per plant with the vermicompost and the mineral fertilizer as compared to the control. The presence of growth regulating enzymes like β-glucosidase, acid phosphatase, arylsulphatase, lipases, chitinases, and readily available nutrients in the vermicompost could be a reason for increase in the growth parameters of the plants [17]. The earthworms secrete enzymes such as proteases, lipases, amylases, cellulases, and chitinases in their intestine which cause rapid biochemical transformation of the cellulosic and proteinaceous components in the organic waste [15].

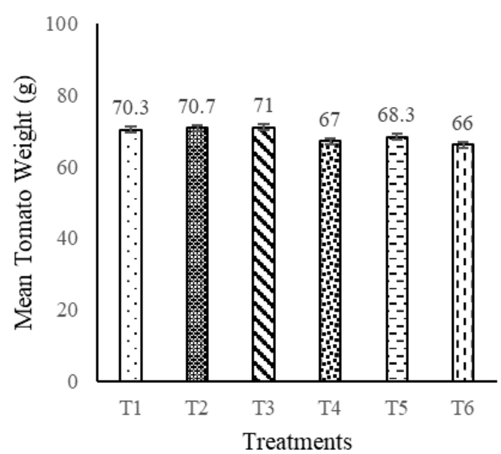

Fig 6. Comparison of mean tomato weight in different treatments

Maximum mean tomato weight is achieved in case of T3 and minimum for T6. The organic fertilizer gave better results in case of T5 than T4 (only compost) and T6 (control) (Figure 6). The maximum percentage increase in the mean tomato weight is achieved for T3 (7.58%) which is followed by T2 (7.08%), T1 (6.56%), T5 (3.53%), and T4 (1.52%). The neem leaves derived vermicompost B (T2) has not shown any significant difference in results as compared with the vermicompost A (T1) at same stock density of the earthworms. Usmani et al. (2019) [10] also observed increased productivity of brinjal and tomato crops by application of fly ash vermicompost. Macronutrients in the vermicompost are reported to improve chlorophyll synthesis, enzyme system, average fruit weight, and growth of the plants [11]. The earthworms are believed to produce humus through biological processes which enhance the plant metabolism and nutrient uptake [14]. The vermicompost reduces salt stress and prevents changes in the amount and type of metabolites that regulate plant growth [18]. The application of the vermicompost has

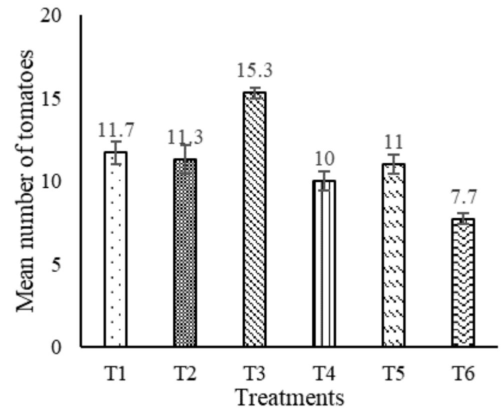

Fig 7. Comparison of mean tomato number in different treatment

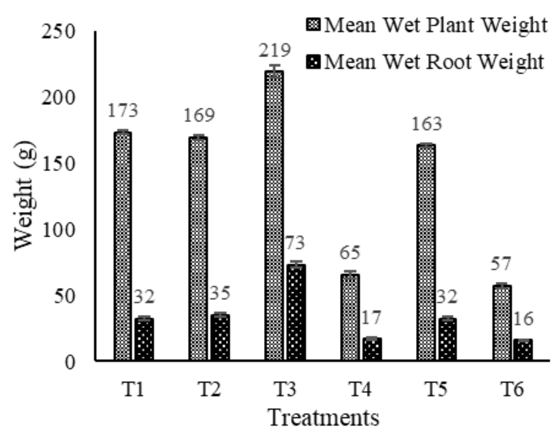

Fig 8. Comparison of mean wet plant weight and wet root weight

been shown to promote plant growth by alteration of the microbiota in rhizosphere and suppression of the plant pathogens [19].

3.5 Pearson correlation

The vermicompost and compost nutritional quality parameters, i.e. total nitrogen (TN), phosphorus (P), total organic carbon (TOC), bulk density, potassium (K), and calcium (Ca) are found to have positive correlation with tomato productivity, i.e. mean tomato number (r=0.047*, r=0.019*, r=0.0017**, r=0.00010**, r=0.015*, and r=0.0026**, respectively).

4 Conclusion

The vermicompost (C) derived with the highest stock density of the earthworms showed the maximum enhancement of growth and yield in the tomato plant. The neem leaves derived vermicompost increased the mean leaf number with no significant influence on the yield of the tomato plants. The findings suggest that the earthworms play a crucial role to improve the physicochemical characteristics of the vermicompost which in turn enhance the growth parameters and productivity. One way ANOVA suggested significant difference ($p < 0.05$) among all the treatments as compared to the control. There is found strong positive correlation between the important physicochemical parameters of the vermicompost, compost, and productivity of the tomato plants. The findings suggest vermicomposting to be an effective method for sustainable management of the rice straw. The vermicompost showed positive influence on the growth and productivity of the tomato plants. The developed vermicompost may be recommended as an effective soil amendment for proper growth and productivity of different crops based on specific nutritional requirements. The vermicomposting is found to be a good alternative for sustainable management of the rice straw and environmental protection.

There exist scope of further studies to explore the earthworm gut microflora and biological processes during vermicomposting, effect of heavy metals on vermicomposting process, and selection of the earthworm species and organic wastes to produce best quality vermicompost.

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