# Asian Journal of Plant Sciences

ISSN 1682-3974

OPEN ACCESS Asian Journal of Plant Sciences
ISSN 1682-3974
DOI: 10.3923/ajps.2023.1.12

# Research Article
# Role of Vermicompost Types (Fish Sludge and Cow Dung) in Improving Agronomic Behavior and Soil Health of Tomato Crop

[1]Yasser Thabet A. Moustafa, [2]Nabil S.A. Mustafa, [3]Mohamad F. El-Dahshouri, [4]Sameh M.M. EL-Sawy, [2]Laila F.Haggag, [5]Lixin Zhang and [6]Raghda Zuhair

[1]Central Lab for Aquaculture Research, Agricultural Research Centre (ARC), Egypt
[2]Pomology Department, National Research Centre (NRC), Egypt
[3]Fertilization Technology Department, Agricultural and Biological Division (NRC), Egypt
[4]Vegetable Research Department, National Research Centre, 33 El Buhouth St, Dokki, Giza, P.O. Box 12622, Egypt
[5]College of Life Sciences, Northwest A and F University, Yangling 712100, Shaanxi, China
[6]Department of Zoology, Faculty of Science, Tanta University, Egypt

## Abstract
**Background and Objective:** Vermicompost technology technique can play as a cost-effective and safe mechanism to agro-waste disposal. The current study aimed to study the impact of vermicompost application on agronomic behaviour of tomato crop and soil health. **Materials and Methods:** An experiment was conducted out in National Research Centre's farm, Northern Egypt, under greenhouse condition to estimate the impact of two types of vermicompost on tomato plants, as well as soil. Fish Sludge (FS) and Cow Dung (CD) were utilized to produce vermicompost. These vermicompost types were applied at different doses during the 2019-2020 growing seasons. **Results:** Vermicompost treatments increased most of the measured vegetative growth parameters and this positive effect increased with increasing doses of applied vermicompost. The high rate of CD (30%) surpassed the other studied treatments in raising N, P, Ca and Mg meanwhile, FS vermicompost at (30%) recorded the highest content of K (2.47%) in tomato leaves. Regarding fruit quality, it was noticed that average fruit weight, lycopene, β-Carotene and acidity significantly affected by the incorporation of vermicompost in the soil as organic fertilizer. Also, soil fertility increased with the application of vermicompost. Application of vermicompost resulted in an increment in soil organic matter, water retention and microbial activity; however soil E.C. decreased with these treatments. **Conclusion:** Vermiculture has positive effects on tomato crop and soil parameters. Besides, it can play an essential role in raising water use efficiency especially in semi and arid countries.

Key words: Cow dung, fish sludge, earthworms, vermicompost fertilizers, tomato crop, soil chemical composition, fruit characteristics, tomato and soil supplement

Citation: Moustafa, Y.T.A., N.S.A. Mustafa, M.F. El-Dahshouri, S.M.M. EL-Sawy, L.F. Haggag, L. Zhang and R. Zuhair, 2023. Role of vermicompost types (fish sludge and cow dung) in improving agronomic behavior and soil health of tomato crop. Asian J. Plant Sci., 22: 1-12.

Corresponding Author: Nabil S.A. Mustafa, Pomology Department, National Research Centre (NRC), Egypt



Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Huge agro-wastes which produced annually may create economic and environmental dilemma especially for countries that build their economy on agricultural sector according to a study by Abou Hussein and Sawan[1]. Vermicompost technology or bioconversion technique can play as a cost-effective and safe mechanism to agro-waste disposal[2]. Whereas, after converting agro-wastes to vermicompost by earthworm, it may represent a valuable source for nutrient and other beneficial compounds such as amino acids and growth promoters[2-5]. During earthworm feeding on agro-wastes not only many nutrients are released but also, the humus like compound are produced[6,7].

According to Margit[5], vermicompost is promising organic manure for better vegetative growth and yield of many plants due to its higher nutritional value than traditional composts. This is due to the increased rate of mineralization and degree of humification by the action of earthworms. Besides, this assumption may be supported by findings of Theunissen *et al.*[8], who reported that reinforcing growth performance of plants may be attributed to the high percentage of humus substances i.e., humic acids, fulvic acids and humin) which provide numerous sites for chemical reaction and microbial components known to enhance plant growth and promote the synthesis of phenolic compounds such as anthocyanins and flavonoids which may improve the plant quality.

Also, Lim *et al.*[9] referred this positive effect of vermicompost application to the role of vermicompost in increasing soil minerals, water holding capacity, soil microorganisms and nutritional values of fruit yield as well as decreases plant pest populations.

Besides, Tesfay *et al.*[10] reported that optimum vermicompost and mineral fertilizer application is crucial for crops (i.e., tomato) production. However, farmers still use inadequate nutrient inputs and inefficient combinations. As a result, unbalanced soil nutrient compositions ultimately lead to a reduction in tomato fruit yield. Also, they emphasize that vermicompost application has a positive effect on tomato fruit yield as the additive application to a recommended fertilizer program.

Based on a study by Gómez-Brandón andDomínguez[3] the maximum growth performance and yield for plants may occur when vermicompost was used by range (20-40%) of the final volume of a container medium mixture. The current work aimed to study how far vermicompost types can enhance tomato crop and maintains soil parameters (i.e., soil fertility and water retention).

## MATERIALS AND METHODS

**Study area:** An experiment was conducted during two growth seasons 2019-2020 (March-July/each season) at National Research Centre's farm, EL-Nubaria Region, EL-Beheira Governorate, Northern Egypt, under greenhouse condition to estimate the impact of two types of vermicompost (Cow Dung (CD) and Fish Sludge (FS)) on vegetative growth of tomato plants, fruit quality as well as soil health.

**Vermicompost production:** Mixing three species of earthworm (*Eisenia fetida*, *Lumbricus rubellus* and *Perionyx excavatus*) were raised on Cow Dung (CD) and Fish Sludge (FS).

### Preparation of different feeding materials

**Cow Dung (CD) processing:** Fresh cow dung was obtained from the cow farms adjacent to the Central Lab for Aquaculture Research (CLAR). It is moistened to 60-70%, assuming the moisture is about 50% of the wet weight, in Styrofoam boxes for 24h and then processed using earthworms.

**Fish Sludge (FS) collection and preparation:** Fish sludge was collected from the concrete ponds of Nile tilapia *Oreochromis niloticus* broodstock and fry, at Nile tilapia hatchery belonging to CLAR; during fry harvesting from the broodstock ponds as well as from fry rearing ponds. The produced FS, with a moisture content of 96.5% and dried solid content of 3.5% was collected in barrels and then spread out in a thin layer on a cement floor for drying over fourteen days, so it can be stored safely until being used.

**Earthworm inoculation and Vermicompost production:** Both fresh cow dung and dried fish sludge were prepared individually and moistened to 60-70% in Styrofoam boxes with dimensions of 60×40× 30 cm. After 24 hrs, three species of earthworm (*Eisenia fetida*, *Perionyx excavatus* and *Lumbricus rubellus*) were added to the media at a rate of 50 g worm per 1000 g media. For 8 weeks the boxes were checked weekly and re-moistened and mixed until the vermicompost matured. A ll boxes were kept indoor and the temperature maintained between 18-25°C during the vermicompost maturation. At harvest time, vermicompost was checked manually on a white plastic surface and the adult, as well as pre-adult earthworms, were collected then the vermicompost w as returned to the boxes again for one more month. Later, the vermicompost was

Table 1: Physiochemical parameters to observe two types of vermicompost and traditional compost

| Parameters | Cow dung vermicompost (CD) | Fish sludge vermicompost (FS) | Compost (control) |
|---|---|---|---|
| OM (%) | 46.6 | 21.06 | 42 |
| Humidity (%) | 33 | 27.33 | 25 |
| Ash | 20.4 | 54.94 | 32.8 |
| C/N ratio | 20.4 | 11.58 | 15.7 |
| N (%) | 1.33 | 1.09 | 1.8 |
| P (%) | 0.35 | 0.4 | 0.8 |
| K (%) | 1.08 | 1.88 | 1.2 |
| Amino acids (mg $g^{-1}$ DW) | 0.27 | 0.44 | 0 |
| ABA (g/100 g) | 0.33 | 0.01 | 0 |
| $GA_3$ (g/100 g) | 1.08 | 0.16 | 0 |
| IAA (g/100 g) | 0.04 | 0.03 | 0 |

ABA: Abscisic acid, $GA_3$: Gibberellic acid, IAA: Indole acetic acid, OM: Organic matter

Table 2: Total bacteria counts in different vermicompost samples (CD and FS)

| Samples | CFU counts $g^{-1}$ vermicompost | Samples | CFU counts $g^{-1}$ vermicompost |
|---|---|---|---|
| Cow dung | 9.62±0.28 | FS alone | 3.48±0.18 |

Total bacteria count was determined as Colony Forming Units (CFU)

Table 3: Antimicrobial activity of vermicompost samples against identified pathogenic bacteria in inhibition zone diameter (mm)

| | *Citrobacter freundii* | *Enterobacter cloacae* | *Pseudomonas aeruginosa* | *Klebsiella pneumonia* |
|---|---|---|---|---|
| CD | 13 mm | 29 mm | 19 mm | 11 mm |
| FS | 20 mm | 19 mm | 12 mm | 18 mm |

CD: Cow dung vermicompost, FS: Fish sludge vermicompost

re-checked again and all hatched earthworms were collected. The harvested vermicompost was packed in plastic bags and samples of these two vermicompost types (CD and FS) delivered to laboratories to be analyzed. Table 1-3 showed results of physicochemical parameters (CD, FS and compost), microbiological activity as Colony Forming Units (CFU) and Antimicrobial activity of vermicompost samples analysis.

**Experimental treatments:** Tomato seedlings that grown under greenhouse conditions were divided into 7 groups (with 3 replicates for each group) as follows:

Group 1 : Tomato plants received recommended dose of compost (control)

Groups 2-4 : Plants received vermicompost produced from fish sludge on three individual levels (10, 20 and 30%) of the total volume of cultivation pots

Groups 5-7 : Plants received vermicompost produced from Cow Dung (CD) at three individual levels (10, 20 and 30%) of the total volume of cultivation pots

Also, all tomato seedlings were received the same recommended agricultural practices from mineral fertilizers, pesticides and irrigation according to the recommendation of the Egyptian Ministry of Agriculture and Land Reclamation for tomato cultivation under sandy soil conditions.

**Analysis of chemical and microbial parameters**

**Vegetative growth parameters:** Average leaf area ($cm^2$), fresh and dry weight of leaves (g), chlorophyll reading (SPAD) and nutrients content were measured.

**Fruit quality parameters:** Average fruit weight (g), chemical parameters (TSS, acidity, TSS: Acidity) and estimation lycopene and β-Carotene was measured according to Nagata and Yamashita[11]. The values of lycopene and β-Carotene were calculated by the following equation:

$$\text{Lycopene (mg/100 mL)} = 0.0458A663+0.204A645+0.372A505-0.0806A453$$

$$\beta\text{-Carotene (mg/100 mL)} = 0.216A663-1.22A645-0.304A505+0.452A453$$

where, A is the absorbance at 663, 645, 505 and 453 nm.

Acidity was determined by titrating 10 g of a homogenized sample of tomato juice, after dilution with 50 mL distilled water, 0.1% NaOH solution at a pH of 8.17[12].

Total Soluble Solids (TSS) were determined by Atago RX 500 digital refractometer[13].

**Leaf nutrient content analysis:** Leaves samples were dried in a ventilated oven at 70°C to constant weight. Samples were ground in a stainless steel mill with a 0.5 mm sieve and kept in plastic containers for chemical analysis. The samples (1 g of each sample) were dry-ashed in a muffle furnace at 450°C for 6 hrs and the ash was dissolved in HCl (2N).

Macronutrients were extracted using the dry ashing digestion method according to Chapman and Pratt[14]. Nitrogen was determined by using the Kjeldahl method, and phosphorus was photometrically determined in the digested solution using vanadate-molybdate colour reaction according to the method described by Jackson[15]. Potassium was measured in the digested suspension using the Flame photometer, (Eppendorf, DR Lang).

**Soil analysis:** Physical parameters of soil, water retention in soil and soil fertility. Soil samples were analyzed for texture, pH and Electric Conductivity (EC) using water extract (1: 2.5) method, total calcium carbonate ($CaCO_3$%) determined with Calcimeter method and for organic matter (O.M%) was determined with using potassium dichromate[14]. Phosphorus was extracted using sodium bicarbonate[16]. Potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) were extracted using ammonium acetate[15]. Iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) were extracted using DTPA[17].

**Soil biological analysis**

**Sampling and sample preparation:** Five grams from soil samples of each treatment were placed in sterile Stomacher bags and treated by a Stomacher 400 Circulator for 60 s at middle speed after adding 45 ml sterile 0.85% NaCl. The Stomacher blending step was repeated three times and the microbial suspension was obtained.

**Estimation the counts of total viable bacteria count:** Tenfold serial dilution of the microbial suspensions obtained with the protocol described above made with sterile 0.85% NaCl were plated onto plate count agar medium for the estimation of total viable counts, counts of colony forming units (CFU) were estimated after 3 days of incubation at 28°C and were calculated per gram vermicompost. The total resistant bacteria were estimated by planting the same dilution onto plate count agar medium sublimated with (20mg/l) for (penicillin, ampicillin, erythromycin and tetracycline respectively).

**Antimicrobial activity assay in inoculated soil with tested organic fertilizers:** This method was done by agar well diffusion test[18] to determine the anti-microbial activity of the vermicompost samples against the selected identified pathogenic bacteria e.g., *Citrobacter freundii*, *Enterobacter cloacae*, *Pseudomonas aeruginosa* and *Klebsiella pneumonia*. The pre-poured nutrient agar plates were overlaid with 100 µL of an overnight culture of tested pathogens (in nutrient broth), then spread well with L-shaped glass rod. After 15 min, wells of 5 mm diameter were made with a sterile cork borer. Samples of vermicompost extract were placed into wells. Plates were then incubated at 30°C for 12 hrs. The inhibition zones were measured to assay the antimicrobial activity of vermicompost samples.

**Data analysis:** All samples were analyzed using the standard procedures in the laboratory at the National Research Centre and Faculty of Science, Tanta University. The treatments were arranged in a Randomized Complete Block Design with three replicates. All data are the means of triplicates. Statistical analysis of data, analysis of variance (ANOVA) and mean separation were carried out using Duncan's multiple range test and significance was determined at the $p \leq 0.05$ level according to Duncan[19]. Data analysis was performed using ASSISTAT version 7.7 beta (2015). Means were represented as the average of replicates of two seasons (as combined analysis of two seasons).

## RESULTS AND DISCUSSION

**Effect of different types and doses of vermicompost on tomato plants**

**Vegetative growth and nutrients content:** Data in Table 4 revealed that high doses of vermicompost whether from FS or CD raised the fresh weight of leaves per plant from (33.33-54.75) and the highest value (54.75 g) of fresh weight was recorded with the highest dose of FS (30%). Meanwhile the lowest value of leaf fresh weight per plant was noticed with untreated plants with vermicompost (control) 33.33 g. Concerning leaves dry weight, vermicompost treatments enhanced dry weight compared with control treatment. Also, increasing dose of applied vermicompost led to increment in dry weight (9.03-9.39) for fish sludge vermicompost and from 8.29-10.12 g for CD vermicompost. Adding CD vermicompost at a rate of 30% of plant pot volume produced the highest significant value (10.12 g) of dry weight. Application of FS vermicompost surpassed CD vermicompost in its positive impact on leaf area and the highest recorded leaf area (4570.11 $cm^2$) was noticed with FS vermicompost at 30% of plant pot volume.

Also, data in Table 4 showed that application vermicompost whether FS or CD significantly raised leaf chlorophyll content to 65.79 SPAD (for treated plants) comparing with untreated tomato plant (control) (35.24 SPAD). The highest values of chlorophyll content (64.79 and

Table 4: Effect of different vermicompost types and doses application on some vegetative growth parameters of tomato plants during 2019 and 2020 seasons (combined analysis of two seasons)

| Treatments | Leaves fresh weight/plant (g) | Leaves dry weight/plant (g) | Leaf area ($cm^2$) | Chlorophyll reading (SPAD) |
|---|---|---|---|---|
| Control | 33.33$^{c}$ | 8.25$^{e}$ | 3303.65$^{b}$ | 35.24$^{c}$ |
| FS vermicompost (10%) | 32.45$^{c}$ | 9.03$^{c}$ | 3268.64$^{b}$ | 44.95$^{bc}$ |
| FS vermicompost (20%) | 43.62$^{bc}$ | 9.28$^{b}$ | 3367.94$^{b}$ | 64.79$^{a}$ |
| FS vermicompost (30%) | 54.75$^{a}$ | 9.39$^{b}$ | 4570.11$^{a}$ | 65.79$^{a}$ |
| CD vermicompost (10%) | 33.50$^{c}$ | 8.29$^{e}$ | 2736.42$^{c}$ | 53.17$^{ab}$ |
| CD vermicompost (20%) | 36.14$^{c}$ | 8.88$^{d}$ | 2633.31$^{c}$ | 63.19$^{a}$ |
| CD vermicompost (30%) | 48.32$^{ab}$ | 10.12$^{a}$ | 3128.59$^{b}$ | 60.57$^{a}$ |

Means were represented as the average of replicates, different letters are express for significant differences while the same letters are non-significant at LSD p>0.05, CD: Cow dung, FS: Fish sludge

Table 5: Effect of different vermicompost types and doses application on leaf nutrients content of tomato plants during 2019 and 2020 seasons (combined analysis of two seasons)

| Treatments | N | P | K | Ca | Mg |
|---|---|---|---|---|---|
| Control | 2.12$^{c}$ | 0.16$^{d}$ | 1.74$^{e}$ | 0.63$^{d}$ | 0.26$^{a}$ |
| FS vermicompost (10%) | 2.27$^{bc}$ | 0.38$^{c}$ | 2.35$^{b}$ | 0.65$^{cd}$ | 0.25$^{ab}$ |
| FS vermicompost (20%) | 2.40$^{b}$ | 0.46$^{b}$ | 2.28$^{b}$ | 0.70$^{bc}$ | 0.24$^{ab}$ |
| FS vermicompost (30%) | 2.43$^{b}$ | 0.58$^{a}$ | 2.47$^{a}$ | 0.70$^{bc}$ | 0.27$^{a}$ |
| CD vermicompost (10%) | 2.27$^{bc}$ | 0.17$^{d}$ | 1.85$^{b}$ | 0.69$^{bc}$ | 0.22$^{b}$ |
| CD vermicompost (20%) | 2.27$^{bc}$ | 0.41$^{bc}$ | 2.17$^{c}$ | 0.72$^{b}$ | 0.24$^{ab}$ |
| CD vermicompost (30%) | 2.57$^{a}$ | 0.55$^{a}$ | 2.30$^{b}$ | 0.87$^{a}$ | 0.26$^{a}$ |

Means were represented as the average of replicates, different letters are express for significant differences while the same letters are non-significant at LSD p>0.05, CD: Cow dung, FS: Fish sludge

65.79 SPAD for FS vermicompost) and (63.19-60.57 SPAD for CD vermicompost) were achieved with 20 and 30% rates vermicompost, respectively without marked differences among these treatments. Generally, vermicompost treatments had a positive effect on most of the determined parameters and that may be contributed to vermicompost contents of amino acids and growth promoters and humus substances, which are probably responsible, partially, for the increased growth parameters[20].

Moreover vermicompost particles bonds with cations quickly, due to their negative charges of the humic acids present in their structures. Thus, they are easily caught by plant roots and enhance the growth of the plant as reported by Canellas *et al.*[21].

These results come in the same line with findings by Azarmi *et al.*[22], who concluded that there is a positive impact for vermicompost application on vegetative growth parameters of tomato plants (*Lycopersicum esculentum* var. Super Beta). Also, these results are supported by the results of Arancon *et al.*[23] who reported that there were positive effects of vermicompost on the growth of strawberry plants, especially increase leaf area and vegetative dry weight in field conditions. Besides, Bejbaruah *et al.*[24] showed that vermicompost had beneficial effects on the growth and yield of rice, especially seeds germination, chlorophyll content and yield production.

Regarding the impact of vermicompost application on nutrients content in tomato leaves, data in Table 5 showed that most nutrients content in leaves increased at different rates by incorporating vermicompost (whether CD or FS) to tomato cultivation medium comparing with control treatment whereas N increased from (2.12% for control) to (2.57% for CD at 30%), P from 0.16% to 0.58 for FS at 30% and 0.55% for CD at 30% and K increased from 1.74% for control treatment to 2.47% with FS at 30%. Meanwhile, Mg had no cleared trend whereas the lowest value (0.24%) of Mg content was achieved with FS and CD at 20%.

Also, it can be noticed that there was gradually enhancement of nutrients content in leaves by increasing doses of applied vermicompost (either FS or CD) individually. For example, when doses of FS vermicompost increased from 10-30%, N increased from 2.27 to 2.43, P from 0.38 to 0.58%, K from 2.35 to 2.47, Ca from 0.65 to 0.70 % and Mg raised from 0.25 to 0.27%. High rate of CD (30%) surpassed studied treatments in raising N (2.57%), P (0.55%) and Ca (0.87%) meanwhile; FS vermicompost at (30%) recorded the highest content of K (2.47%) in leaves. In respect for Mg, most applied vermicompost doses didn't produce noticed differences except CD at 20% recoded the lowest significant level in Mg and the highest values were achieved with FS at 30% (0.27) and 0.26% in both the control and CD vermicompost at a rate of 30%.

The achieved results may explained by the considerable contents of nutrients, amino acids, hormones, active enzymes and beneficial microorganisms in vermicompost, which suggesting vermicompost as an effective soil amendment

Table 6: Effect of different vermicompost types and doses application on some fruit quality parameters of tomatoes during 2019 and 2020 seasons during 2019 and 2020 seasons (combined analysis of two seasons)

| Treatments | Average fruit weight (g) | Lycopene (mg $kg^{-1}$ FW) | β-Carotene (mg $kg^{-1}$ FW) | TSS (%) | Acidity (%) | TSS acidity |
|---|---|---|---|---|---|---|
| Control | $51.00^{b}$ | $35.00^{c}$ | $24.34^{b}$ | $11.13^{a}$ | $0.57^{c}$ | $19.60^{a}$ |
| FS vermicompost (10%) | $56.07^{b}$ | $62.81^{ab}$ | $37.03^{ab}$ | $12.53^{a}$ | $0.71^{a}$ | $17.55^{a}$ |
| FS vermicompost (20%) | $58.41^{b}$ | $70.53^{a}$ | $32.10^{b}$ | $12.93^{a}$ | $0.65^{ab}$ | $19.92^{a}$ |
| FS vermicompost (30%) | $86.46^{a}$ | $66.67^{ab}$ | $34.57^{ab}$ | $12.77^{a}$ | $0.68^{ab}$ | $18.78^{a}$ |
| CD vermicompost (10%) | $50.86^{b}$ | $45.48^{bc}$ | $34.22^{ab}$ | $12.6^{a}$ | $0.72^{a}$ | $17.45^{a}$ |
| CD vermicompost (20%) | $80.15^{a}$ | $61.02^{ab}$ | $32.22^{b}$ | $12.13^{a}$ | $0.68^{ab}$ | $17.73^{a}$ |
| CD vermicompost (30%) | $77.68^{a}$ | $75.9^{a}$ | $39.7^{a}$ | $11.43^{a}$ | $0.62^{bc}$ | $18.56^{a}$ |

Means were represented as the average of replicates, different letters are express for significant differences while the same letters are non-significant at LSD p>0.05, CD: Cow dung, FS: Fish sludge

mean. Moreover, vermicompost has a positive impact on soil structure (for instance improving porosity and water holding capacity), all these factors were reflected in the enhancement of root system and uptake rate as having been reported by several authors. There are many pieces of evidence that vermicompost contains the most nutrients in plant-available forms such as nitrate, phosphate and exchangeable calcium and soluble potassium as reported by Orozco *et al.*[25].

Besides, there are raising scientific clues that vermicomposts can influence the growth and productivity of plants markedly[26]. Various greenhouse and field studies have examined the effects of a variety of vermicomposts on a wide range of crops including cereals and legumes[27], vegetable[28], ornamental and flowering plants[29], field crops[30] and lemon[31]. Annual application with enough amounts of vermicompost derived to the significant increase in soil enzyme activities such as urease, phosphomonoesterase, phosphodiesterase and arylsulphatase[32]. Plant growth-promoting bacteria directly stimulate growth by nitrogen fixation[33], solubilization of nutrients[34], production of growth hormones, 1-amino-cyclopropane-1-carboxylate deaminase[35]. Besides, its positive impact extended to physical properties such as bulk density, water holding capacity and total porosity and microorganism's activity in soil[22,36]. All aforementioned facts about vermicompost may interpret the beneficial effect of vermicompost.

Finally, several authors indicated that vermicompost contains humus substances that can play a vital role in reinforcing plant growth of carrots, tomatoes and peppers[20,37]. They also, suggested that humic acid may absorb plant hormones and/or itself has hormone ability to affect plant growth.

**Tomato fruit quality:** Data in Table 6 showed that average fruit weight, lycopene, β-Carotene and acidity were significantly affected by the incorporation of vermicompost in the soil as organic fertilizer. However, TSS and TSS acidity ratio didn't markedly differ by adding vermicompost. In more details, it was noticed that high FS vermicompost at (30%) and CD vermicompost treatments at (20 or 30%) were more effective than other treatments in increasing average fruit weight (86.46, 80.5 and 77.68 g, respectively) comparing with control (51 g). In respect for lycopene content in tomato fruit, the same trend of average fruit weight was found for the impact of vermicompost treatments on lycopene content, whereas the high doses of both FS and CD vermicompost doses (20 or 30%) recorded the highest value of lycopene content (70.53, 66.67, 61.02 and 75.9 mg $kg^{-1}$ FW, respectively) without markedly differences among these treatments. For β-Carotene, the trend was different from those in both of average fruit weight and lycopene, whereas the lowest doses of FS vermicompost (10%) was recorded high value of β-Carotene (37.03 mg $kg^{-1}$ FW) and the highest dose of CD vermicompost (30%) was recorded the highest value of β-Carotene (39.7 mg $kg^{-1}$ FW) without any significant differences among them. Also, for acidity, it was noticed that low doses of FS and CD vermicompost (10%) were recorded higher values of acidity (71 and 72%, respectively) and there were no significant differences between these two treatments. Moreover, acidity values decreased with increment doses of FS and CD vermicompost. Finally, in all aforementioned parameters, it was noticed that control treatment had the lowest values of the parameters. However, the trend was entirely different for both TSS and TSS acidity parameters whereas there was no markedly significant effect for all vermicompost treatments.

These positive effects of vermicompost treatments may be referred to their contents of nutrients, amino acids and growth promoters that encouraged tomato plants growth and resulted in improving the fruit quality. In this concern, Arancon *et al.*[30] interpreted the positive impact of vermicompost on pepper yield due to factors such as an improvement of the physical structure of the potting medium (soil), increases in populations of beneficial microorganisms and the potential availability of plant growth-influencing-substances produced by microorganisms in vermicomposts. Besides, Zaller[38] reported that chemical tomato fruit parameters were significantly affected by vermicompost

Table 7: Effect of vermicompost types and doses on physical parameters and water retention in soil during 2019 and 2020 seasons (combined analysis of two seasons)

| Treatments | pH | EC (dS $m^{-2}$) | OM (%) | $CaCO_3$ (%) | Water retention in soil |
|---|---|---|---|---|---|
| Control | $7.22^{f}$ | $3.34^{a}$ | $0.58^{c}$ | $1.75^{d}$ | $2.30^{b}$ |
| FS vermicompost (10%) | $7.76^{c}$ | $2.00^{c}$ | $0.68^{b}$ | $1.92^{b}$ | $3.00^{ab}$ |
| FS vermicompost (20%) | $7.82^{b}$ | $1.86^{d}$ | $0.48^{e}$ | $1.83^{c}$ | $3.30^{ab}$ |
| FS vermicompost (30%) | $7.96^{a}$ | $1.73^{e}$ | $0.75^{a}$ | $2.27^{a}$ | $4.50^{a}$ |
| CD vermicompost (10%) | $7.49^{e}$ | $1.73^{e}$ | $0.58^{c}$ | $1.40^{e}$ | $4.00^{a}$ |
| CD vermicompost (20%) | $7.64^{d}$ | $1.77^{e}$ | $0.34^{f}$ | $1.74^{d}$ | $3.00^{ab}$ |
| CD vermicompost (30%) | $7.65^{d}$ | $2.49^{b}$ | $0.51^{d}$ | $1.75^{d}$ | $4.30^{a}$ |

Means were represented as the average of replicates, different letters are express for significant differences while the same letters are non-significant at LSD p>0.05, CD: Cow dung, FS: Fish sludge

Table 8: Effect of vermicompost types and doses on soil fertility during 2019 and 2020 seasons (combined analysis of two seasons)

| Treatments | K | Mg | Ca | Fe | Mn | Zn | Cu |
|---|---|---|---|---|---|---|---|
| | (mg/100 g) | | | (ppm) | | | |
| Control | $9.20^{b}$ | $0.65^{c}$ | $380^{a}$ | $2.48^{c}$ | $6.20^{a}$ | $2.79^{e}$ | $1.50^{a}$ |
| FS vermicompost (10%) | $7.80^{c}$ | $0.72^{b}$ | $240^{d}$ | $2.32^{d}$ | $3.80^{c}$ | $2.79^{e}$ | $1.20^{b}$ |
| FS vermicompost (20%) | $7.80^{c}$ | $0.75^{a}$ | $230^{d}$ | $2.81^{a}$ | $3.80^{c}$ | $3.15^{d}$ | $0.90^{c}$ |
| FS vermicompost (30%) | $7.20^{d}$ | $0.71^{b}$ | $280^{c}$ | $2.16^{e}$ | $5.20^{b}$ | $3.42^{b}$ | $0.90^{c}$ |
| CD vermicompost (10%) | $9.60^{a}$ | $0.64^{c}$ | $240^{d}$ | $2.65^{b}$ | $5.00^{b}$ | $2.79^{e}$ | $1.50^{a}$ |
| CD vermicompost (20%) | $9.00^{b}$ | $0.65^{c}$ | $240^{d}$ | $2.16^{e}$ | $5.20^{b}$ | $3.78^{a}$ | $0.60^{d}$ |
| CD vermicompost (30%) | $9.00^{b}$ | $0.62^{d}$ | $310^{b}$ | $1.67^{f}$ | $6.20^{a}$ | $3.24^{c}$ | $1.20^{b}$ |

Means were represented as the average of replicates, different letters are express for significant differences while the same letters are non-significant at LSD p>0.05, CD: Cow dung, FS: Fish sludge

amendments. Also, Ávila-Juárez *et al.*[39] mentioned that adding vermicompost leachates into the irrigation system with tomato plants had a positive effect on the lycopene content in tomato fruits.

Huber *et al.*[40] reported that utilizing vermicompost as organic fertilizers have increased the levels of nutrients and carotenoids (lycopene and β-Carotene) in tomato fruits. Furthermore, Truong *et al.*[41] showed that the addition of vermicompost significantly improved the physic-chemical media (soil) properties, increasing the EC and also increasing the macronutrients in the media resulting in substantially increased fruit quality of tomato fruits.

On the other hand, Gutiérrez-Miceli *et al.*[42] reported that the addition of vermicompost decreased juice acidity and increased soluble and insoluble solids of tomato fruits, compared to those harvested from plants cultivated in untreated soil.

**Physicochemical parameters:** Data in Table 7 concerns the impact of vermicompost applications on the physical properties of soil, it is clear that soil Electrical Conductivity (EC) was markedly decreased from 3.34 to 1.73 dS $m^{-2}$ with adding vermicompost in most vermicompost treatments compared with control treatment. Also, the Organic Matter (OM) was positively increased with adding vermicompost from 0.58% for control to 0.75% with applying vermicompost especially FS at 30%. Besides, it was clear that there is a considerable effect of vermicompost application on water retention in soil whereas, water retention increased from 2.3 to 4.5 days by increment doses of FS vermicompost from 0 to 30%. Moreover, applying CD vermicompost with 10, 20 and 30% raise the water retention (4, 3 and 4.3 days, respectively) comparing with control treatment (2.3 days). The obtained results that focus on EC and water retention may be attributed to increasing organic matter in the soil as consequences of adding vermicompost to the soil. Also, several studies indicated that vermicompost has a positive effect in enhancing soil structure and porosity. As Atiyeh *et al.*[20] showed that the electrical conductivity of vermicompost depends on the raw materials used for producing vermicompost and their ions concentration.

Meanwhile, $CaCo_3$ (%) has a different trend and that may be referred to using crushed shells from eggs to adjust media pH to be suitable for earthworm growth and vermicomposting the organic matter (fish sludge, cow dung and agricultural waste).

Vermicompost application was led to decreasing EC as compared with control and this was supported with finding by Wang *et al.*[43]. In addition, Atiyeh *et al.*[44] noticed that there was a positive correlation between water holding capacity in soil and rates of application of vermicompost.

Xu and Mou[45] showed that applied vermicompost as a soil amendment may lead to improve soil structure and increase porosity thereby increase water retention in soil.

Moreover, several studies figured out that during organic wastes decomposition by earthworm and microbial activities, byproducts are produced such as polysaccharides that can work on the aggregation of soil particles that will lead to improving porosity of soil and increasing water retention[45-48].

Data in Table 8 represented the impact of vermicompost on soil fertility. Cow dung vermicompost treatments surpassed all treatments and recorded the highest values of K and Cu (9.6 mg/100 g soil and 1.5 ppm, respectively) with a 10% dose of CD vermicompost. Meanwhile, all FS vermicompost treatments recorded the lowest K content in soil (7.2-7.8 mg/100 g soil). For Mg content in the soil, the trend has differed whereas the FS vermicompost treatments surpassed other treatments in its content of Mg (0.75%). At the same time, CD vermicompost treatments recorded the lower Mg content in soil (0.62-0.65 mg/100 g soil).

Data in Table 8 revealed that $Ca^{+2}$ content in soil untreated with vermicompost recorded higher content (380 mg/100 g soil) of this ion comparing with those treated with two types of vermicompost that ranged from (2.30-310 mg/100 g soil). These results may be attributed to vigour growth of plants on soil treated with different types and doses of vermicompost whereas more amount of $Ca^2$ was uptake via these plants and that can interpret why the high doses of both types of vermicompost recorded lower value of $Ca^{+2}$ content. For Mn and Cu, it was found that both of them recorded higher levels in control treatment however their levels were low in all vermicompost treatments and these results may be explained because of vegetative growth results for tomato plants that increased as consequences of vermicompost application.

The trend that can be noticed with Fe revealed that soil treated with low doses of the same type of vermicompost had a higher content of Fe (2.81ppm) with FS vermicompost at 20% and (2.65ppm) with CD vermicompost at 10% rather than that treated with higher doses (30%). Meanwhile, this trend has differed slightly in Zn content in the soil. Whereas, it found that most vermicompost treatments resulted in enhancing Zn levels in soil (3.15-3.78 ppm) with rat 20 and 30% of both types of vermicompost comparing with control treatment (2.79 ppm).

Generally, the obtained results indicated that vermicompost raised most determined nutrients as reported by Chatterjee *et al.*[49], who showed that using vermicomposts as amendments led to an increase in soil fertility.

Obtained results may be illustrated in the light of four facts, first fact; vermicompost is containing a mass of humus substances. These substances in vermicompost exhibit a buffering property over a wide pH range that is why soil treated with vermicompost has a considerable amount of nutrients. The second one; vermicompost particle has a negative charge due to the presences of humus substance so that it can trap cations and adhere plant roots at the same time as reported by Canellas *et al.*[21], which may lead to keeping nutrient elements in the root zone and decrease their leaching and loss in the soil. The third fact, vermicompost does not only contain microbial biomass however it helps in increasing microbial biomass concentration and their enzymes activities (i.e., phosphatase enzyme) in soil[50]. These enzymes may work on facilitation nutrients plants uptake. Fourth fact, vigour plant growth rates associated almost with depletion nutrients from soil nutrient store. Thereby, when discussing the impact of studied treatments on soil nutrient content, it should put into consideration the growth rates of plants under these treatments.

Besides, the obtained results by Truong *et al.*[41] showed that adding vermicompost to soil may have resulted in an increment in P, K, Ca and Mg content in the cultivation medium. Besides, Xu and Mou[45] mentioned those earthworms can reinforce microbial activities due to their mucus and casts, which will be responsible later for better decomposition and mineralization, thereby a high amount of nutrients, will be available for plants. They also, indicated that vermicompost is preferable over compost to improve soil quality. It can be applied as a soil amendment to improve soil fertility by increasing soil organic matter, nutrient content and improve soil structure[51].

Mustafa *et al.*[52] reported that the effect of vermicompost application is not only exclusive for plant growth but also extended in regulating soil pH, increasing Electrical Conductivity (EC) and soil fertility. Moreover, vermicompost enriches the soil with biomass of beneficial microbes that help in enriching the soil with nutrients (whether macro and micro) in available forms for plants. Finally, Patham and Sakthivel[53] stated that earthworm activity profoundly affects the physical, chemical and biological properties of soil.

**Impact of vermicompost on microbial activity in soil:** Adding Fs vermicompost has a positive impact on beneficial microorganism communities in the soil (Table 9). It was found that there was an increment in this positive effect with increasing applied doses from (10-20%) of FS vermicompost whereas CFU increased from 2.32-2.38, respectively in comparison with control treatment that recorded CFU (2.19). The trend has differed in CD vermicompost treatments

Table 9: Effect of vermicompost on microorganism's activity (CFU) in the soil at the end of the experiment during 2019 and 2020 seasons (combined analysis of two seasons)

| Treatments | Log (CFU $mL^{-1}$) |
|---|---|
| Compost (control ) | 2.19[ab] |
| FS vermicompost (10%) | 2.32[a] |
| FS vermicompost (20%) | 2.38[a] |
| FS vermicompost (30%) | 2.17[ab] |
| CD vermicompost (10%) | 1.65c |
| CD vermicompost (20%) | 2.04[b] |
| CD vermicompost (30%) | 1.84[c] |

Means were represented as the average of replicates. Different letters are express for significant differences while the same letters are non-significant at LSD p>0.05, CD: Cow dung, FS: Fish sludge

Table 10: Antimicrobial activity in the treated soil during 2019 and 2020 seasons (combined analysis of two seasons)

| Treatments | *Citrobacter freundii* (mm) | *Enterobacter cloacae* (mm) | *Pseudomonas aeruginosa* (mm) | *Klebsiella pneumonia* (mm) |
|---|---|---|---|---|
| Control | 10±0.15 | 0 | 0 | 13±0.15 |
| FS vermicompost (10%) | 8±0.103 | 15±1.09 | 12±0.34 | 0 |
| FS vermicompost (20%) | 14±0.21 | 17±0.65 | 8±0.5 | 0 |
| FS vermicompost (30%) | 15±0.15 | 6±0.14 | 0 | 0 |
| CD vermicompost (10%) | 17±0.76 | 35±1.13 | 0 | 0 |
| CD vermicompost (20%) | 18±0.93 | 18±0.78 | 15±0.65 | 17±1.5 |
| CD vermicompost (30%) | 11±0.21 | 21±0.43 | 0 | 15±0.88 |

Means were represented as the average of replicates, CD: Cow dung, FS: Fish sludge

whereas CFU was low (that ranged from 1.65-2.04) than control treatment (2.19) and that may be referred to the competition among these microorganisms in the present low amount of organic matter in the tested soil (sandy soil).

Generally, adding vermicompost to soil increase soil microorganism's communities in soil and this positive effect increase with increasing doses of applied vermicompost. The drastic increase in microbial population diversity and density immediately upon application of vermicompost fertilizers may be due to their priming effect[54]. The inclusion of organic fertilizers (green manure, compost and vermicompost) may accelerate soil organic matter mineralization, as indicated by some researchers[55]. Although the actual mechanism of the priming effect is still not clearly understood, a conceptual model as conceived by Fontaine *et al.*[54] showed that the priming effect may result mainly from an increase in the microbial community's overall activity due to higher availability of energy and nutrients from organic fertilizer input. The immense microbial diversity of the soil in nature results in a selection process in which microbes with faster adaptive capacity for the organic matter of the soil grow profusely, improving their growth and population, while the others remain dormant. Besides, organic matter incorporation (in the form of compost and vermicompost) can activate the dormant microbial strains that may contribute to the dormant microbial strains. The effect is quite rapid and within the addition of vermicompost, drastic changes in the community dynamics are observed. As nutrients in the substrate are exhausted, the rate of enzyme production decreases, leading to an initial increase and then a reduction in the microbial population. The initial rise in microbial population and diversity in control plants could have been due to plant root exudates[56].

Besides general trend in this study is agreed with the findings of Pathma and Sakthivel[53] who reported that vermicompost enhances soil biodiversity by promoting the beneficial microbes. Moreover many studies mentioned that vermicompost products are superior to other organic fertilizers in terms of microbial activities of bacteria, actinomycetes and fungi[57,58]. This increment of microbial activity may be reversed to the opposite side of the amount of organic matter that doesn't match with this activity.

Finally, the positive role for vermicompost application in increment soil microflora may be attributed to the effect of earthworm during vermicomposting the organic matters thereby provide suitable meals and conditions for aerobic and anaerobic microbes to live and do their function in decomposition these organic wastes and finally, reproduction and increasing these soil microorganism's communities[59].

Data in Table 10 showed the residual antimicrobial impact of applied vermicompost. Extractions of samples of treated soil with different types and doses were prepared to study its ability to suppress the growth rate of different bacteria (*Citrobacter freundii*, *Enterobacter cloacae*, *Pseudomonas aeruginosa* and *Klebsiella pneumonia*) at finally this suppression was measure by inhibition zones with each type of bacterial. Results revealed that most treated soil with vermicompost possess the ability to suppress the growth of

(*Citrobacter freundii* and *Enterobacter cloacae* whereas the inhibition zone ranged from (8±0.103-18±0.93 mm) and (6±0.14-35±1.3 mm) respectively. Also, CD vermicompost surpassed FS vermicompost in inhibition effect on *Citrobacter freundii* with inhibition zone ranged from 11±0.21-18±0.93 mm comparing with FS vermicompost which produced inhibition zone ranged from 8±0.103 to 15±0.15 mm. Also, the same trend of suppressing effect for CD vermicompost on *Enterobacter cloacae* produced inhibition zone ranged from 18±0.78-35±1.13 mm and surpassed. However, FS vermicompost produced inhibition zone ranged from 6±0.14-17±0.65 mm with *Enterobacter cloacae*. In respect to *Pseudomonas aeruginosa* data in Table 10 showed a similar trend which emphasizes on surpassing CD vermicompost in inhibition effect and producing inhibition zone ranged from 0 to 15±0.65 comparing with FS vermicompost that produced inhibition zone ranged from 0 to 12±0.34 mm. However, CD vermicompost can depress the growth of *Klebsiella pneumonia* comparing with that treated with FS vermicompost. Finally, when comparing these results with results of both two types of vermicompost (CD and FS) extracts before adding to soil, it may be figured out that the antimicrobial effect will be lost by time. This is considered the important view to removing any doubts about the risky of utilizing vermicompost as organic fertilizers. This drooping in antimicrobial activity for the vermicompost may be related to the absences of earthworm, because of fact that several enzymes, intestinal mucus and antibiotics are produced in earthworm's intestinal tract[53]. Besides, Vasanthi *et al.*[51] reported that earthworms live in an environment filled with various kinds of pathogens. In such environment, it must have efficient defence mechanisms. This defence system depends on excreting mucus that covers its bodies, mucus contains effective anti-microbes. These anti-microbial compounds are transferred to vermicompost during the movement of these earthworms and their activity. Vermicompost that used in the field is free from earthworm which will be utilized in vermicompost production, feeding fish or farm birds.

## CONCLUSION

Such this study came to provide more pieces of evidence the earthworm activity profoundly affects the physical, chemical and biological properties of soil. Also, it highlights on role of vermicompost in enhancing water retention in the soil thereby raising water use efficiency.

## SIGNIFICANCE STATEMENT

"This study emphasized that vermicompost is an effective organic fertilizer that contains several beneficial compounds such as nutrients, amino acids, growth promoters, humus compounds and microorganisms, which improved the vegetative growth and fruit quality of tomato plants. Moreover, vermicompost has a promising role under drought stress whereas it raises water retention in soil and porosity and needs more effort to study for how far it can improve water use efficiency, especially in the semi-arid and arid region.

## ACKNOWLEDGMENTS

This paper is based upon work supported by Science, Technology and Innovation Funding Authority (STDF) under the grant (Egypt-China Cooperation Program: "Chinese-Egyptian Research Fund" (CERF) Project ID (30359). Also, our gratitude extends to the National Research Centre (NRC) that facilitated the conduction of this work.

Our thanks are also extended to Dr. Yasser Thabet A. Moustafa from the Central Laboratory for Aquaculture Research (CLAR), Agricultural Research Centre (ARC) for his efforts in producing vermicompost according to the experimental needs in his Lab. as well as for his fruitful discussions.

## REFERENCES

1. Hussein, S.D.A.A. and O.M. Sawan, 2010. The utilization of agricultural waste as one of the environmental issues in Egypt (A case study). J. Appl. Sci. Res., 6: 1116-1124.
2. Rupani, P.F., M.H. Ibrahim and S.A. Ismail, 2013. Vermicomposting biotechnology: Recycling of palm oil mill wastes into valuable products. Int. J. Recycl. Org. Waste Agric., Vol. 2. 10.1186/2251-7715-2-10.
3. Gomez-Brandón, M. and J. Domınguez, 2014. Recycling of solid organic wastes through vermicomposting: Microbial community changes throughout the process and use of vermicompost as a soil amendment. Crit. Rev. Environ. Sci. Technol., 44: 1289-1312.
4. Alphonsine, K. and W. Blok, 2012. Vermicompost as a component in potting mixes for growth promotion in ornamental plants. Rwanda J., 28: 53-63.
5. Olle, M., 2016. The effect of vermicompost based growth substrates on tomato growth. J. Agric. Sci., 27: 38-41.
6. Khwanchai, K. and S. Kanokkorn, 2018. Effect of agricultural waste on vermicompost production and earthworm biomass. J. Environ. Sci. Technol., 11: 23-27.

7. Muscolo, A., F. Bavolo, F. Gionfriddo and S. Nardi, 1999. Earthworm humic matter produces auxin-like effects on *Daucus carota* cell growth and nitrate metabolism. Soil Biol. Biochem., 31: 1303-1311.
8. Theunissen, J., P.A. Ndakidemi and C.P. Laubscher, 2010. Potential of vermicompost produced from plant waste on the growth and nutrient status in vegetable production. Int. J. Phys. Sci., 5: 1964-1973.
9. Lim, S.L., T.Y. Wu, P.N. Lim and K.P.Y. Shak, 2015. The use of vermicompost in organic farming: Overview, effects on soil and economics. J. Sci. Food Agric., 95: 1143-1156.
10. Tesfay, T., M. Gebremariam, K. Gebretsadik, M. Hagazi and S. Girmay, 2019. Tomato yield and economic performance under vermicompost and mineral fertilizer applications. Open Agric. J., 12: 262-269.
11. Nagata, M. and I. Yamashita, 1992. Simple method for simultaneous determination of chlorophyll and carotenoids in tomato fruit. J. Jpn. Soc. Food Sci. Technol., 39: 925-928.
12. Thakur, B.R., R.K. Singh and P.E. Nelson, 1996. Quality attributes of processed tomato products: A review. Food Rev. Int., 12: 375-401.
13. Barrett, D.M., E. Garcia and J.E. Wayne, 1998. Textural modification of processing tomatoes. Crit. Rev. Food Sci. Nutr., 38: 173-258.
14. Chapman, H.D. and P.F. Pratt, 1979. Methods of Analysis for Soils, Plants and Waters. 2nd Edn., University of California Press, Berkeley, CA., USA PP: 12-19.
15. Wenzel, W., 1959. Wagner, F.: Die technische Durchführung von Feldversuchen. Paul Parey Verlag, Berlin und Hamburg 1959. 162 S. 63 Abb. DM 19.80 J. Plant Nut. Soil Sci., 85: 250-251.
16. Olsen, S.R., C.V. Cole, F.S. Watamable and L.A. Dean, 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. US Department Agric. Circ., 939: 1-19.
17. Lindsay, W.L. and W.A. Norvell, 1978. Development of DTPA micronutrient soil tests for zinc, iron, manganese and copper. Soil Sci. Soc. Am. J., 42: 421-428.
18. Schillinger, U. and F.K. Lucke, 1989. Antibacterial activity of Lactobacillus sake isolated from meat. Applied Environ. Microbiol., 55: 1901-1906.
19. Duncan, D.B., 1955. Multiple range and multiple F tests. Biometrics, 11: 1-42.
20. Atiyeh, R.M., S. Lee, C.A. Edwards, N.Q. Arancon and J.D. Metzger, 2002. The influence of humic acids derived from earthworm-processed organic wastes on plant growth. Bioresour. Technol., 84: 7-14.
21. Canellas, L.P., F.L. Olivares, A.L. Okorokova-Facanha and A.R. Facanha, 2002. Humic acids isolated from earthworm compost enhance root elongation, lateral root emergence and plasma membrane $H^+$-ATPase activity in maize roots. Plant Physiol., 130: 1951-1957.
22. Azarmi, R., P.S. Ziveh and M.R. Satari, 2008. Effect of vermicompost on growth, yield and nutrition status of tomato (*Lycopersicum esculentum*). Pak. J. Biol. Sci., 11: 1797-1802.
23. Arancon, N.Q., C.I. Edwards, P. Bierman, C. Welch and T.D. Metzger, 2004. In fluences of vermicomposts on field strawberries: 1. Effect on growth and yields. Bioresour. Technol., 93: 145-153.
24. Bejbaruah, R., R.C. Sharma and P. Banik, 2013. Split application of vermicompost to rice (*Oryza sativa* L.): Its effect on productivity, yield components and N dynamics. Org. Agr., 3: 123-128.
25. Orozco, F.H., J. Cegarra, L.M. Trujillo and A. Roig, 1996. Vermicomposting of coffee pulp using the earthworm *Eisenia fetida*: Effects on C and N contents and the availability of nutrients. Biol. Fertil. Soils, 22: 162-166.
26. Edwards, C.A., 1998. The Use of Earthworms in the Breakdown and Management of Organic Wastes. In: Earthworm Ecology, Edwards, C.A. (Ed.). CRC Press LLC, Boca Raton, Fl., ISBN: 084931819X, pp: 327-354.
27. Kaushik, P. and V.K. Garg, 2003. Vermicomposting of mixed solid textile mill sludge and cow dung with the epigeic earthworm *Eisenia foetida*. Bioresour. Technol., 90: 311-316.
28. Tomati, U., E. Galli, A. Grappelli and G. Dihena, 1990. Effect of earthworm caste on protein synthesis in radish (*Raphanus sativus*) and lettuce (*Lactuca sativa*) seedlings. Biol. Fertil. Soils, 9: 288-289.
29. Atiyeh, R.M., S. Subler, C.A. Edwards, G. Bachman, J.D. Metzger and W. Shuster, 2000. Effects of vermicomposts and composts on plant growth in horticultural container media and soil. Pedobiologia, 44: 579-590.
30. Arancon, N.Q., C.A. Edwards, R.M. Atiyeh and T.D. Metzger, 2004. Effect of vermicomposts produced from food waste on the growth and yields of greenhouse peppers. Bioresour. Technol., 93: 139-144.
31. Mustafa, N.S., I.A. Matter, H.R. Abdalla, M.F. El-Dahshouri, Y.A.T. Moustafa and N.S. Zaid, 2019. The promotive effects of some natural extracts (algal, yeast and vermiwash) on vegetative characteristics and nutrients status of citrus lemon (*Citrus aurantifolia*) seedlings. Net. J. Agric. Sci., 7: 43-49.
32. Albiach, R., R. Canet, F. Pomares and F. Ingelmo, 2000. Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. Bioresour. Technol., 75: 43-48.
33. Han, J., L. Sun, X. Dong, Z. Cai, H. Yang, Y. Yang and W. Song, 2005. Characterization of a novel plant growth-promoting bacteria strain *Delftia tsuruhatensis* HR4 both as a diazotroph and a potential biocontrol agent against various pathogens. Syst. Appl. Microbiol, 28: 66-76.
34. Rodriguez, H. and R. Fraga, 1999. Phosphate solubilizing bacteria and their role in plant growth promotion. Biotechnol. Adv., 17: 319-339.

35. Donate-Correa, J., M. Leon-Barrios and R. Perez-Galdona, 2005. Screening for plant growth-promoting rhizobacteria in *Chamaecytisus proliferus* (tagasaste), a forage tree-shrub legume endemic to the Canary Islands. Plant Soil, 266: 261-272.
36. Azarmi, R., M.T. Giglou and R.D. Taleshmikail, 2008. Influence of vermicompost on soil chemical and physical properties in tomato (*Lycopersicum esculentum*) field. Afr. J. Biotechnol., 7: 2397-2401.
37. Arancon, N.Q., C.A. Edwards, S. Lee and R. Byrne, 2006. Effects of humic acids from vermicomposts on plant growth. Eur. J. Soil Biol., 42: S65-S69.
38. Zaller, J.G., 2007. Vermicompost as a substitute for peat in potting media: Effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. Sci. Hortic., 112: 191-199.
39. Ávila-Juárez, L., A.R. González, N.R. Piña, R.G.G. González, I.T. Pacheco, R.V. Velázquez and B. Moustapha, 2015. Vermicompost leachate as a supplement to increase tomato fruit quality. J. Soil Sci. Plant Nutr., 15: 46-59.
40. Huber, M., E. Rembiałkowska, D. Średnicka, S. Bügel and L.P.L. van de Vijver, 2011. Organic food and impact on human health: Assessing the *status quo* and prospects of research. NJAS-Wagen. J. Life Sci., 58: 103-109.
41. Truong, H.D., C.H. Wang and T.T. Kien, 2018. Effect of vermicompost in media on growth, yield and fruit quality of cherry tomato (*Lycopersicon esculentun* Mill.) under net house conditions. Compost Sci. Util., 26: 52-58.
42. Gutierrez-Miceli, F.A., J. Santiago-Borraz, J.A.M. Molina, C.C. Nafate and M. Abud-Archila *et al*., 2007. Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersicum esculentum*). Bioresour. Technol., 98: 2781-2786.
43. Wang, X.X., F. Zhao, G. Zhang, Y. Zhang and L. Yang, 2017. Vermicompost improves tomato yield and quality and the biochemical properties of soils with different tomato planting history in a greenhouse study. Front. Plant Sci., Vol. 8. 10.3389/fpls.2017.01978.
44. Atiyeh, R.M., C.A. Edwards, S. Subler and J.D. Metzger, 2001. Pig manure vermicompost as a component of a horticultural bedding plant medium: Effects on physicochemical properties and plant growth. Bioresour. Technol., 78: 11-20.
45. Xu, C. and B. Mou, 2016. Vermicompost affects soil properties and spinach growth, physiology and nutritional value. Amer. Soci. Horticult. Sci., 51: 847-855.
46. Atiyeh, R.M., J. Dominguez, S. Sulber and C.A. Edwards, 2000. Change in biochemical properties of cow manure during processing by earthworms (*Eisenia andrei*. Bouche) and the effects on seedling growth. Pedobiologia, 44: 709-724.
47. Padmavathiamma, P.K., L.Y. Li and U.R. Kumari, 2008. An experimental study of vermin-biowaste composting for agricultural soil improvement. Bioresour. Technol., 99: 1672-1681.
48. Srivastava, P.K., P.C. Singh, M. Gupta, A. Sinha and A. Vaish *et al*., 2011. Influence of earthworm culture on fertilization potential and biological activities of vermicomposts prepared from different plant wastes. J. Plant Nutr. Soil Sci., 174: 420-429.
49. Chatterjee, R., S. Gajjela and R.K. Thirumdasu, 2017. Recycling of organic wastes for sustainable soil health and crop growth. Int. J. Waste Resour., Vol. 7. 10.4172/2252-5211.1000296.
50. Şahin, S. and S.B. Atakli, 2019. The effect of different phosphorus doses on the growth of pepper seedling (*Capsicum annuum* L.). Asian J. Adv. Agric. Res., 11: 1-4.
51. Vasanthi, K., K. Chairman and A.J.A.R. Singh, 2013. Antimicrobial activity of earthworm (*Eudrilus eugeniae*) paste. Afr. J. Environ. Sci. Technol., 7: 789-793.
52. Mustafa, C., S. Şahin and M. Erman, 2018. Effects of vermicompost on plant growth and soil structure. Selcuk J. Agr. Food Sci., 32: 607-615.
53. Pathma, J. and N. Sakthivel, 2012. Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. Springer Plus, Vol. 1. 10.1186/2193-1801-1-26.
54. Fontaine, S., A. Mariotti and L. Abbadie, 2003. The priming effect of organic matter: A question of microbial competition. Soil Biol. Biochem., 35: 837-843.
55. Birk, J.J., C. Steiner, W.C. Teixiera, W. Zech and B. Glaser, 2009. Microbial Response to Charcoal Amendments and Fertilization of a Highly Weathered Tropical Soil. In: Amazonian Dark Earths: Wim Sombroek's Vision, Woods, W.I., W.G. Teixeira, J. Lehmann and C. Steiner (Eds.), Springer, Dordrecht, Netherlands, ISBN: 978-1-4020-9031-8, pp: 309-324.
56. Maji, D., P. Misra, S. Singh and A. Kalra, 2017. Humic acid rich vermicompost promotes plant growth by improving microbial community structure of soil as well as root nodulation and mycorrhizal colonization in the roots of *Pisum sativum*. Appl. Soil Ecol., 110: 97-108.
57. Huang, K., F. Li, Y. Wei, X. Chen and X. Fu, 2013. Changes of bacterial and fungal community compositions during vermicomposting of vegetable wastes by *Eisenia foetida*. Bioresour. Technol., 150: 235-241.
58. Emperor, G.N. and K. Kumar, 2015. Microbial population and activity on Vermicompost of *Eudrilus eugeniae* and *Eisenia fetida* in different concentrations of tea waste with cow dung and kitchen waste mixture. Int. J. Curr. Microbiol. App. Sci., 4: 497-506.
59. Maboeta, M.S. and L. von Rensburg, 2003. Vermicomposting of industrially produced woodchips and sewage sludge utilizing *Eisenia fetida*. Ecotoxicol. Environ. Safety, 56: 265-270.