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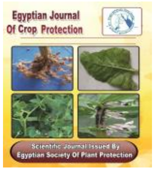


# Potential of different compost types in enhancement of physiological, biochemical parameters and control of *Meloidogyne javanica* in tomato plants

**Ramadan A. Bakr*[1]; Ahmed M. Abdelall[2] and Mohamed F. Salem[3]**

[1]*Plant Pathology Branch, Department of Agricultural Botany, Faculty of Agriculture, University of Menoufia, 32514 Shibin El-Kom, Egypt*

[2] *Plant Physiology Branch, Department of Agricultural Botany, Faculty of Agriculture, University of Menoufia, 32514 Shibin El-Kom, Egypt*

[3]*Organic Agriculture Research Unit, Department of Environmental Biotechnology, Genetic Engineering and Biotechnology Research Institute, GEBRI, P.O. Box:79, University of Sadat City, Egypt*

## ABSTRACT

Biological control of root-knot nematodes using organic amendments such as compost and *Trichoderma* has been recommended as an alternative effective strategy in disease management and stimulating the chemical and physiological aspects of tomato plants. In this experiment, four types of compost at three doses were evaluated for their efficacy in the root-knot nematode (*Meloidogyne javanica*) control and physiological traits of tomato plants under greenhouse conditions. Results showed that amending the soil of the pot with the compost markedly reduced the root-knot nematode related parameters in tomato plants. The root galling, egg masses and females were decreased in the treated plants compared with infected non-treated control plants. Mixed type at 3% had a phytotoxicity effect in tomato plants. Supplemented the soils with the compost also inhibited the population of second-stage juveniles (J2s) in the soil. All compost type (Animal, plant, Trichoderma Biofortified, and mixed) increased significantly plant height, leaf area fresh and dry weight, photosynthetic pigments, total and soluble carbohydrates, proline and phenol concentrations as well as and water balance occurred in tissues of tomato plants. Meanwhile, the third level of all organic fertilizers caused a significant decrease in all growth characteristics of tomato plants. Thus, the current study results confirmed that compost could offer a satisfactory sustainable ecofriendly tactic for root-knot nematodes management and soil fertility improvement.

**Key words:** *Meloidogyne javanica*, root-knot nematodes, biological control, compost.

## INTRODUCTION

Crops play the main role in people's food security, but their production yield is limited by various biotic and a-biotic factors, including Plant Parasitic Nematodes (PPN). Root-knot nematodes (RKNs) are considered the most predominant pathogenic nematodes and limiting factor widely distributed in economic and non-economic crops all over the world especially in the newly reclaimed sandy soils (Bakr *et al*., 2011, 2020).

Important consideration must be taken to RKNs, as they can increase rapidly the

*Corresponding author email: ramadanbaker82@agr.menofia.edu.eg

population build-up in a short time all over the year especially in the tropics and sub-tropics which subsequently affects the crops production quantity and quality (Agrios, 2005; Perry and Moens, 2013). The annual losses exceed $400 million (Huang *et al*., 2014). From 2011-2012 the estimated annual yield losses in tomatoes due to damage by plant parasitic nematodes in Egypt reached 12% with 1753.17 Million L.E. (Abd-El Gawad 2014). Severity infected plants suffer from abnormal physiological traits, stunting, root galls and low yield production (Bakr *et al*. 2017; Abd-Elgawad,2021). The losses may be varying according to many factors such as, nematode initial population at the transplanting, plant cultivars, presence of other plant pathogens, soil type and area weather conditions (Bakr and Ketta, 2018).

For decades, different methods can be used for root-knot nematode management. Solarization, resistant cultivars, crop rotation, and chemicals were effective tools (Bakr *et al*.,2013; Haydock *et al*.,2013). Currently, nematode management with the synthetic chemical nematicides is deleterious to soil microflora, humans, and other organisms in the ecosystem. According to the excessive use of chemical fertilizers and pesticides chemicals accumulate in plants or plant fruits. Over the last five decades, these chemicals, whether pesticides or chemical fertilizers are dangerous to human and animal health as well as water (Abd El-All, 2019). Consequently, due to the focus of attention on environmental biosafety, various active ingredient nematicides have been severely restricted and become absent in the markets which limits PPN control options (Renco and Kovacik, 2012; Burns *et al*.,2017). Therefore, it is urgent to use a novel alternative, ecofriendly management strategies for root-knot nematodes management Barros *et al*., (2021). Using organic amendments such as compost is an alternative and suitable approach tract for controlling RKNs (Renco *et al*., 2016 and Bakr 2018; Al-Hendy *et al*., 2021). Organic amendments originally came from a different animal and plant residues in the agroindustry. The use of organic amendments helps in minimizing the agrochemical synthetic inputs and reducing the farming activity residues (Varo-Su_arez *et al*., 2017). Organic fertilizer is one of the most important safely agriculture practices in the world, that is friendly and safe for the environment, plants, animals and humans. Organic fertilizer is very important for organic farming, which gives plants and fruits free from the accumulation of chemicals.

Using of organic amendments is suitable for poor rural farmers especially in a developing countries. In addition, they can use as to increase organic matter, and natural fertilizers, and reduce soil-borne pathogens in soil (Mehta *et al*., 2014). Decomposition of organic matter into the soil releases some organic compounds such as acetic acid, propionic, and butyric acid that may be toxic to nematodes. Composting is a good suitable method for the biological stabilization of solid organic waste by using microorganisms to degrade the waste organic matter under controlled conditions. Pathogenic microorganism’s eradicate during the thermophilic stage at 45-65°C is recommended (Edwards *et al*., 2010).

Compost can be made from huge types of agricultural waste products usually dispose of (wheat and rice straw, orange peels etc.) and animal manures (Buffalo, cow, Poultry, etc.) can be used separated or mixed at different values. During the last decade, great attention was condensing in the using of compost as degradable material in the management of PPN as a safe eco-friendly method (Arancon *et al*., 2004). Using of co-composting additives such as accelerators and microbial inoculums leads to an easy rapid composting process (Gabhane *et al*.,2012). Moreover, the addition of some biological control agents to compost has been reported to establish an organic fertilizer with a great suppressive potency (Mhatre *et al*., 2019; Zhao *et al*., 2019).

Combination and enriched compost with *Trichoderma* or bio-control or botanicals could provide a variable potential effect in soil born and PPN management and enhances the growth of tomato (Atandi *et al*., 2017 and dos Santos *et al*., 2020) as a result of efficacy improvement of the compost after amended by bio-control agent (Dukare *et al*., 2011). Trichoderma was one of the most fasting colonizing the organic amendments raw material during compost processing. Trichoderma is a genus of fungi widely considered antagonistic agents against a wide spectrum of plant pathogens. Nowadays, the researcher pointed out the attention on using Trichoderma as an alternative safe option to pesticides which encourages and increased the distribution of Trichoderma commercial products in the markets (Woo *et al*., 2014). Several Trichoderma species present antagonistic potentials against pathogenic fungi and nematodes under laboratory and pots experiments (Abdelatief and Bakr, 2018; Khalifa *et al*., 2019; Hewedy *et al*.,2020). Trichoderma-based compost was used for plant parasitic nematode control strategy and increased the organic production yield of tomatoes (Atungwu *et al*., 2018). Egyptian new reclaimed lands are characterized by low fertility and soil-borne pathogens. Using compost is suitable solutions for contributing to soil nutrients and plant pathogens management.

The objective of this study was to evaluate the suppressive effects of different antagonistic compost types with various doses on tomato with special references to its morphological and physiological traits and control of root-knot nematode *M. javanica* under glasshouse conditions.

## MATERIALS AND METHODS

### Source and mass production of *Trichoderma harzianum*

Pure culture of *T. harzianum* were obtained from Department of Agricultural Botany, Faculty of Agriculture, Menoufia University, Egypt. Then grown on the potato dextrose agar medium (PDA) at 28 ± 2°C for 5 days. Pure cultures of the isolates maintained on PDA slants and kept at 4°c for further studies.

For mass production of *T. harzianum* was done on sterilized rice bran and spent mushroom compost media (Two kilograms of rice bran was blended, sieved using a 3 mm mesh +3 kg of spent mushroom compost + 5 g of sugar). The media moisture level was adjusted to 40% using distilled water and well mixing. After that the prepared media were fill in autoclavable polypropylene bags (15×20 cm) and autoclaved at 121ºC (15 psi) for 25 minutes. Afterward, each polypropylene bags inoculated with 2×2 cm mycelial disc of 7 days old *T. harzianum* grown on PDA under sterile conditions then incubated at 28 ± 2ºC for 20 days.

### Compost types and preparation process:

- Animal compost (AC): consisting of cow manure and rice straw bedding composted outdoors for 45 days in static piles turned every 2 weeks.

- Plant compost (PC): consisting of sugarcane mud and spent mushroom compost composted outdoors for 45 days in static piles turned every 2 weeks.

- Trichoderma biofortified compost (TC): consisting of 50% Animal Compost +50% Plant Compost + *Trichoderma harzianum* at $10^6$ CFU/kg compost.

- Mixed compost (MC): consisting of 50% Animal Compost + 50% Plant Compost.

**Pot experiment:**

Pot experiment was carried out under greenhouse conditions, at Faculty of Agriculture, Menoufia University. This experiment was conducted to study the effect of different four types and concentrations of compost i.e. Animal compost (AC), Plant compost (PC), Trichoderma Biofortified Compost (TC) and Mixed compost (MC) with different chemical composition as illustrated in Table (1) on growth, water relations, chemical constituents and control of root-knot nematode *M. javanica* on tomato plants. Plastic pots (25cm in dim) were filled with clay /sandy soil. Each pot received treatments at four rates of 1, 3 and 5 % of soil weight while control pots serve as control. The control pots were fertilized at the agriculture ministry recommended rates of N, P and K fertilizers. For nematode inoculation preparation, pure culture of *M. javanica* identified by observation of perineal patterns according to Hartman and Sasser (1985) maintenances in tomato plants at glass house at Faculty of Agriculture, Menoufia University. Root-knot nematodes eggs were extracted from tomato roots infested with *M. javanica* using sodium hypochlorite (NaOCl) technique described by Hussey and Barker, (1973). Then pots received approximately 2000 of *M. javanica* eggs while un-infested pots consider as positive control. Pots wetted with water and keep at greenhouse. After seven days Three weeks old tomato seedlings Cv. Beto 86 were transplanted in treated pots and treatments were replicated six times.

Two months after seedlings transplanting, tomato plants were removed and carefully washed the roots by running tap water and used the plants for the next determines as follow:

**1. Vegetative growth characters:**

Root volume ($cm^3$), plant height (cm), leaf area per plant ($cm^2$ / plant). (Fladung and Ritter, 1991), fresh and dry weight of hole plant (g) (Plant materials were dried in an electric oven at 70$^o$C for 72 hours).

**2. Water relations:**

Total water content (TWC, %), free and bound water (Gosev, 1960 and Kreeb, 1990), relative water content (RWC, %) (Barrs and Weatherley, 1962), osmotic pressure (Gosev, 1960), transpiration rate (Kreeb, 1990) and plasma membrane integrity (PM) (%).

**3. Photosynthetic pigments**:

The photosynthetic pigments were extracted from fresh leaf sample (fourth upper leaf) by 85 % acetone according to the method described by Wettestein's formula in A.O.A.C., 1995.

**4. Chemical analysis:**

Total carbohydrates and total sugars were determinate using the phenol sulfuric acid method as described by A.O.A.C. (1995). Proline concentration was measured according to the ninhydrin method by Bates *et al*. (1973).

N, P and K were determined as a described by A.O.A.C. (1995).

**5. Nematode analysis:**

Two months after nematodes inoculation, Plant were uprooted and wash carefully to remove soil debris then roots were stained using Phloxine-B technique as described by Daykin and Hussey (1985) by dipping the roots in 0.015% Phloxine-B stain solution for 20 min then washed well by water to remove remains stain and the number of egg masses and galls /root system calculated. After that root were keep in water at room temperature until soften then females were extracted by washing the soften roots through 250 and 500 µm sieves. Number of females /root system were performed according to Bakr (2017) using stereomicroscope. Number of J2s / 250gm soil calculated using Baermann trays technique.

**5. Statistical analysis:**

All data collected were subjected to the standard statistical analysis following the proceeding described by Gomez and Gomez (1984) using the computer program of Costat Software (1985). The analyzed data then presented in Tables.

**Table 1: The Nutrient composition and characteristics of used compost types.**

| Component | Compost Type | | | |
|---|---|---|---|---|
| | Animal | Plant | Trichoderma Biofortified | Mixed |
| N (%) | 1.35 | 2.0 | 1.8 | 1.25 |
| P (%) | 0.61 | 4.2 | 3.4 | 0.48 |
| K (%) | 1.28 | 0.38 | 0.94 | 1.62 |
| Ca (mg/kg) | 1.39 | 0.8 | 1.34 | 1.07 |
| Mg (mg/kg) | 1.02 | 0.66 | 0.87 | 0.25 |
| S (mg/kg) | 208.4 | 2.78 | 186.4 | 187.6 |
| Fe (mg/kg) | 105.3 | 3.70 | 90.4 | 114.5 |
| Mn (mg/kg) | 201.8 | 4.2 | 112.4 | 164.1 |
| Zn (mg/kg) | 377.5 | 65.7 | 216.8 | 293.4 |
| Cu (mg/kg) | 38.9 | 23.7 | 19.6 | 9.63 |
| pH | 8.30 | 5.46 | 4.7 | 6.19 |
| Organic carbon (%) | 18.31 | 44.15 | 30.65 | 18.11 |
| Organic Matter OM | 31.58 | 74.76 | 54.27 | 31.18 |
| C/N ratio | 13:1 | 22:1 | 17:1 | 14:1 |
| EC dS/m | 65.0 | 1.7 | 36.7 | 57.8 |

**RESULTS**

Data in Table (2) demonstrated that the first and the second levels of all compost types (Animal, plant, Trichoderma Biofortified and mixed) increased significantly plant height, leaf area fresh and dry weight of tomato plants. Meanwhile, the third level of all organic fertilizers caused a significant decrease in all growth characters of tomato plants, also, there's unaffected results in root volume at all treatments of organic fertilizers. The highest increase in all growth characteristics was recorded at the first level of mixed compost followed by the second level of mixed compost treatments as compared with the control plants. Phyto-toxicity of the highest rates of mix compost cause death of tomato plants in all replicates. The illustrated data in Table (3) showed that, all compost types such as Animal, plant, Trichoderma and mixture caused a balance in water relations in tomato leaves, which treated with different compost types. All compost types caused significantly increase in TWC, RWC, meanwhile not affected on free water, bound water, O.P., Transpiration rate and PM in leaves of tomato plants. The highest value in water relations balance was recorded at the 1st level of animal fertilizer followed by the 1st level of mixture organic fertilizer treatments as compared with the control nematode plants.

The recorded data in Table (4) indicated that, in leaves of tomato plants fertilized by all levels of used organic fertilizers, there was a remarkable gradual increase in total carbohydrates, total soluble sugars and total protein. Meanwhile, there was a significant decrease in proline content at the same treatments. In this regard, the highest increase in chemical measures was recorded at mixture 1 organic fertilizer.

Data illustrated in Table (5) showed the reduction of *M. javanica* number of J2S / 250gm soil and galls, egg-masses and females on tomato plant root system as a result of addition of different compost types as pre-planting applications at three rates of 1, 3 and 5 % of pot weight in comparison with untreated control under glass house conditions.

According to obtained results, all the tested compost types were effective in reducing the nematode root galling and inhibiting the nematode reproduction on tomato root systems. However, there was variation among the different compost doses in reducing nematode parameters. All tested concentrations reduced all the related nematode parameters and efficacy of such treatments was increased as dosage increased. The highest concentration of plant was the most effective one in reducing significantly ($P \leq 0.05$) number of J2S / 250gm soil followed by Trichoderma Biofortified compost at the same concentration while the lowest reduction was obtained by animal compost at the used low concentration as presented in Fig. (1).

Examination of root system revealed that those treatments significantly ($P \leq 0.05$) decreased the number of galls/tomato root system. Fewer number of galls were recorded in tomato infected roots from compost-treated plants compared to untreated infected plants roots. Application of plant compost at the highest concentration recorded the highest reduction in number of galls/root system followed by Trichoderma Biofortified compost at the same concentration compared with inoculated untreated plants as shown in Fig. (2).

Observation of root system after staining and counted the number of egg masses and females /root system revealed that a similar trend was noticed for egg masses and female numbers. As illustrated in figs. (3and4), the highest reduction in egg mass and female numbers/root system were recorded with the highest concentration of plant compost followed by the highest concentration of Trichoderma Biofortified compost in comparison with untreated control.

**Table 2: Impact of compost types on growth characters of tomato plants infected with *M. javanica* under greenhouse conditions.**

| Characters / Treatments | Root volume ($cm^3$) | Plant height (cm) | Leaf area ($cm^2$) | Fresh weight (g) | Dry weight (g) |
|---|---|---|---|---|---|
| Animal 1 | 5.00 | 51.35 | 170.81 | 33.94 | 3.47 |
| Animal 2 | 4.50 | 50.75 | 113.00 | 27.65 | 2.75 |
| Animal 3 | 4.50 | 41.65 | 109.72 | 22.93 | 2.28 |
| Plant 1 | 5.80 | 54.85 | 178.96 | 34.03 | 3.58 |
| Plant 2 | 2.50 | 39.25 | 121.63 | 17.23 | 1.71 |
| Plant 3 | 1.00 | 29.75 | 66.95 | 9.56 | 0.95 |
| Trichoderma 1 | 5.00 | 59.50 | 193.38 | 22.18 | 2.20 |
| Trichoderma 2 | 4.50 | 49.00 | 118.27 | 18.59 | 1.85 |
| Trichoderma 3 | 3.50 | 46.00 | 167.37 | 16.51 | 1.64 |
| Mixed 1 | 5.00 | 54.77 | 181.86 | 20.88 | 2.01 |
| Mixed 2 | 4.30 | 50.53 | 106.97 | 16.70 | 1.56 |
| Mixed 3 | - | - | - | - | - |
| Nematode alone | 6.50 | 39.74 | 97.15 | 16.91 | 1.72 |
| Control | 3.50 | 41.85 | 122.97 | 17.71 | 1.86 |
| **LSD at 5%** | **ns** | **0.123** | **1.291** | **0.087** | **0.008** |

**Table 3: Impact of compost types on water relations of tomato plants infected with *M. javanica* under greenhouse conditions.**

| Characters / Treatments | TWC (%) | Free water (%) | Bound water (%) | RWC (%) | O.P. C.S. (bar) | Trans rate (mg/g fw.h) | Plasa. Memb Perm. (%) |
|---|---|---|---|---|---|---|---|
| Animal 1 | 86.82 | 12.58 | 74.24 | 73.83 | 9.43 | 0.025 | 39.00 |
| Animal 2 | 82.33 | 12.50 | 69.83 | 73.95 | 9.05 | 0.026 | 38.00 |
| Animal 3 | 83.85 | 12.62 | 71.23 | 73.22 | 7.86 | 0.025 | 38.00 |
| Plant 1 | 82.06 | 12.62 | 69.44 | 72.28 | 8.38 | 0.026 | 35.00 |
| Plant 2 | 82.29 | 13.22 | 69.07 | 72.66 | 7.44 | 0.025 | 35.00 |
| Plant 3 | 83.53 | 12.69 | 70.84 | 73.83 | 7.58 | 0.025 | 37.00 |
| Trichoderma 1 | 81.91 | 12.45 | 69.46 | 72.62 | 7.73 | 0.026 | 37.00 |
| Trichoderma 2 | 82.92 | 13.46 | 69.46 | 74.42 | 7.66 | 0.024 | 36.00 |
| Trichoderma 3 | 81.55 | 13.17 | 68.38 | 71.85 | 6.90 | 0.025 | 35.00 |
| Mixed1 | 86.97 | 13.45 | 73.52 | 76.60 | 7.83 | 0.027 | 38.00 |
| Mixed 2 | 86.91 | 13.78 | 73.13 | 77.65 | 7.88 | 0.027 | 37.00 |
| Mixed 3 | - | - | - | - | - | - | - |
| Nematode alone | 82.60 | 12.52 | 70.08 | 71.63 | 9.83 | 0.025 | 37.00 |
| Control | 86.42 | 12.96 | 73.46 | 77.18 | 9.15 | 0.027 | 39.00 |
| **LSD at 5%** | **0.053** | **0.007** | **0.077** | **0.019** | **0.081** | **0.0001** | **ns** |

**Table 4: Impact of compost types on chemical compositions of tomato plants infected with *M. javanica* under greenhouse conditions.**

| Characters / Treatments | Chl. A. (mg /g dwt) | Chl. B. (mg /g dwt) | Carotenoide (mg /g dwt) | Total carbohydrates (mg /g dwt) | Total sugars (mg/g dwt) | Protein (%) | Proline (µg lucine /g dwt) |
|---|---|---|---|---|---|---|---|
| Animal 1 | 3.10 | 1.02 | 1.29 | 0.846 | 0.017 | 25.24 | 248.52 |
| Animal 2 | 2.93 | 1.01 | 1.22 | 0.819 | 0.015 | 23.86 | 283.63 |
| Animal 3 | 2.99 | 1.03 | 1.24 | 0.822 | 0.014 | 24.35 | 271.48 |
| Plant 1 | 2.93 | 1.03 | 1.21 | 0.826 | 0.014 | 23.83 | 280.15 |
| Plant 2 | 2.93 | 1.08 | 1.20 | 0.829 | 0.014 | 23.88 | 279.25 |
| Plant 3 | 2.98 | 1.03 | 1.23 | 0.833 | 0.016 | 24.26 | 261.35 |
| Trichoderma 1 | 2.92 | 1.00 | 1.21 | 0.817 | 0.014 | 23.78 | 288.62 |
| Trichoderma 2 | 2.96 | 1.10 | 1.21 | 0.833 | 0.016 | 24.10 | 273.96 |
| Trichoderma 3 | 2.91 | 1.07 | 1.19 | 0.815 | 0.014 | 23.69 | 289.68 |
| Mixed 1 | 3.11 | 1.11 | 1.25 | 0.852 | 0.018 | 25.32 | 240.72 |
| Mixed 2 | 3.12 | 1.14 | 1.27 | 0.866 | 0.018 | 25.40 | 240.19 |
| Mixed3 | - | - | - | - | - | - | - |
| Nematode alone | 2.88 | 1.00 | 1.16 | 0.795 | 0.013 | 23.45 | 292.47 |
| Control | 3.09 | 1.06 | 1.28 | 0.824 | 0.016 | 25.16 | 267.78 |
| **LSD at 5%** | **0.028** | **0.039** | **0.027** | **0.005** | **0.0009** | **0.045** | **1.077** |

**Table (5): Impact of compost types on nematode parameters of tomato plants infected with *M. javanica* under greenhouse conditions**

| Characters / Treatments | J2S / 250gm soil | Nematode parameters/Root system | | |
|---|---|---|---|---|
| | | Galls | Egg masses | Females |
| Animal 1 | 106.33 | 67.00 | 78.33 | 84.00 |
| Animal 2 | 36.66 | 25.00 | 17.66 | 19.33 |
| Animal 3 | 19.33 | 12.66 | 10.33 | 11.33 |
| Plant 1 | 39.66 | 24.00 | 14.00 | 17.33 |
| Plant 2 | 31.00 | 10.33 | 7.66 | 8.33 |
| Plant 3 | 14.00 | 5.00 | 3.33 | 4.33 |
| Trichoderma 1 | 47.66 | 26.00 | 18.66 | 20.66 |
| Trichoderma 2 | 23.33 | 10.00 | 17.66 | 8.00 |
| Trichoderma 3 | 16.33 | 7.00 | 5.66 | 6.66 |
| Mixed 1 | 43.33 | 29.00 | 16.00 | 20.00 |
| Mixed 2 | 35.66 | 20.00 | 14.66 | 18.66 |
| Mixed 3 | - | - | - | - |
| Nematode alone | 341.66 | 184.33 | 158.66 | 168.33 |
| **LSD at 5%** | **8.80** | **9.40** | **6.49** | **6.87** |

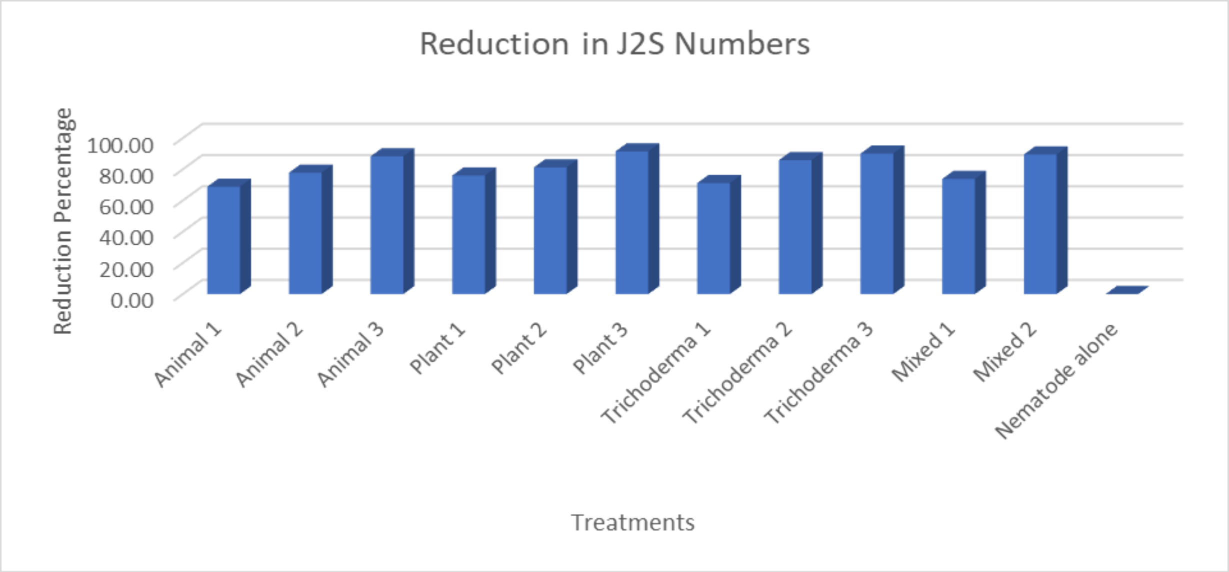


**Fig. (1): Effect of different compost types on reduction percentage of J2s/250gm soil.**

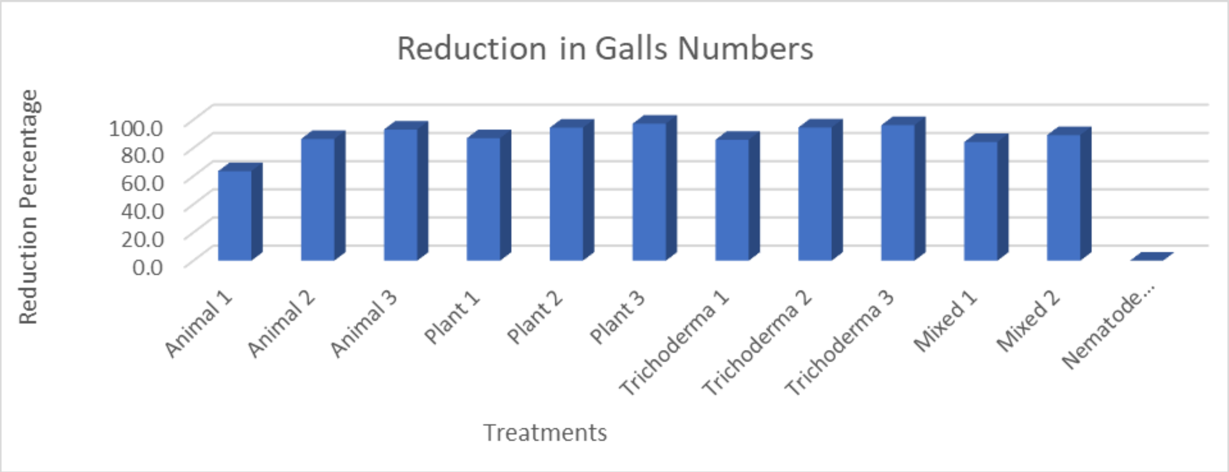


**Fig. (2): Effect of different compost types on reduction percentage of galls number / tomato root system.**

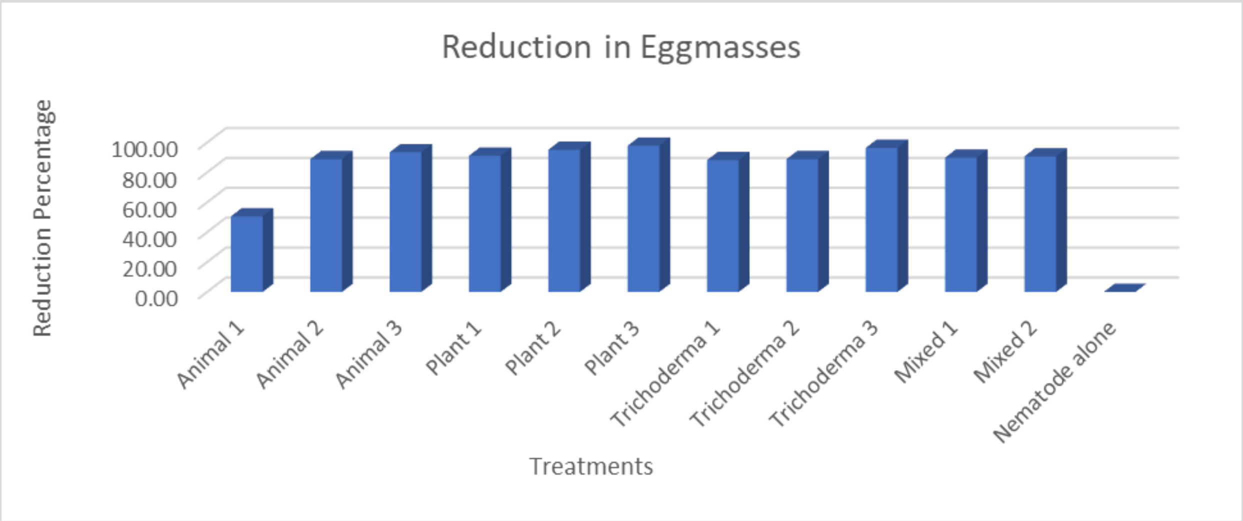


**Fig. (3): Effect of different compost types on reduction percentage of egg masses number / tomato root system.**

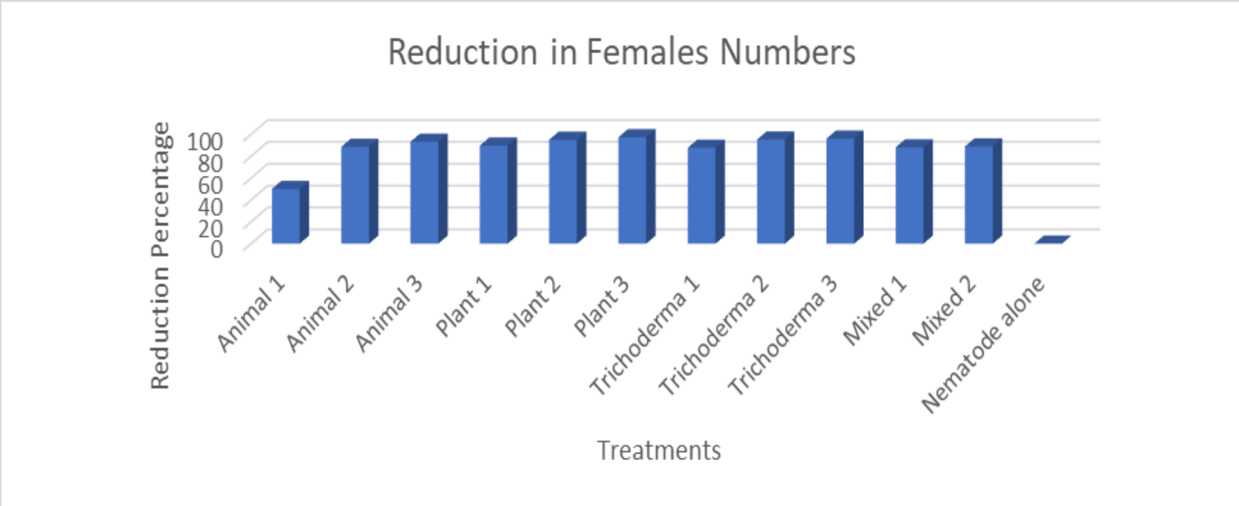


**Fig. (4): Effect of different compost types on reduction percentage of female's number/ tomato root system.**

## DISCUSSION

Root-knot nematode is belonging to the most threats' pathogens to vegetable crops. The present study emphasized that all tested treatments exhibited a variable potential nematicidal activity against RKN infecting eggplant. However, farmers usually dispose of agricultural waste. Besides the documented suppressive effect of various compost types against PPN it can improve soil health and structure. Biological fertilizers are one of the most important sources of mineral nutrition for plants, as they are useful in controlling PH. If a good nutrition for plants occurs, a balance occurs in water relations within plant tissues, enzymatic activity, and chemical content, which is reflected in the growth of plants and production quantity and quality in addition to increasing the plants resistance to the pathogens (Al-Hendy *et al*.,2021). Improved plant growth in tomato where compost was applied as expected as a response to additions of organic matter to the soil. Conversely it can be used as a rich source of plant nutrients such as, nitrogen, phosphorus, and potassium which succeeded to improve plant growth criteria in addition to their role as a soil conditioner and organic matter contents. Our findings in this study indicated the potential of using compost treatments for nematode control. We have to emphasize that the great difference between considering functional compost to be considered as a soil conditioner and soil fertilizer and the key factor in this issue is the Carbon: Nitrogen ratio (C:N ratio).

These results in accordance with Acatrinel (2010) who found that, the stomatal conductivity of water was in generally correlated with the transpiration process and is concerning the state of leaf dehydration. The dependency on the type of technology is related to the decomposition rate of nutrient from the soil and to the entering into metabolism (photosynthesis and carbon assimilation); in synthetic fertilizers nutrients are available quickly, while using organic nutrients released slowly in the soil during vegetation duration.

These results are in agreement with those obtained results by Hou *et al*., (2013) who reported that, Organic fertilizers can be helpful to improve the leaf photosynthetic rates and photosynthesis of tomatoes and Xu et *al*., (2000) who cited that, concentrations of sugars and organic acids were higher in the fruit of tomato plants fertilized with bokashi (organic fertilizer) than in fruit of other treatments.

In reference to the Table of the analysis of bio-organic fertilizers, we note that, the containment of fertilizers on a good level of different minerals and important for the growth of all plants. In addition, it also contains a percentage of organic matter suitable for the growth of plants as well as that improves the rhizosphere area biologically and chemically. All these factors have shown us an optimal balance in the water content of tomato plants. This balance has resulted in good and very well vegetative characters and an increase in photosynthetic pigments, which in turn are reflected on the process of photosynthesis and formation of sugars inside plant cells, which also related to all metabolic processes. This has been observed in proline deficiency, which indicates plant growth under good conditions. Proline may be converted into protein. Based on these factors, the good growth (vegetative, physiological, and chemical) for the tomato plants is obtained from grown in soil fertilized by bio-organic fertilizers. This leads to a good harvest in terms of quantity and quality (Abd El-All, 2019). The use of composted organic fertilizer results in several benefits such as better soil structure; a build-up of antagonistic organisms and a supply of nutrients (Akhtar and Siddiqui, 2008)

Moreover, the functional composts i.e., Trichoderma and Mixture as acidic composts with range 4.7 to 6.1 and this is because of the content of the organic acid that improve the absorbance of the major and minor nutrients (Dar *et al*., 2012; Brust, 2019 and Hwang 2020). The nematicidal effect of the used treatments may be related to the decomposition process of organic matter involved in the used compost which releases some nematode-toxic organic compounds in the soil such as acetic acid, butyric and propionic acid. The mode of action in nematode suppression may depend on the C: N ratio in the selected treatments and the time of microbial decomposition of the used materials (Rodriguez-Kabana *et al*., 1995; D'Addabbo and Sasanelli, 1997; Akhtar and Malik, 2000). Using materials with lower C:N ratios present nematicidal effect more than those with higher ratios (Renčo *et al*. 2011). Enhancement and development of nematode competitors, antagonists and parasites on the feeding substrate provided by the compost is another suggested mechanism of RKN population reduction (Rodríguez-Kábana *et al*., 1986).

Obtained results agree with those by dos Santos *et al*., (2020) who reported that enriched compost with Trichoderma induce tomato plants tolerance against *M. incognita* and enhances the growth parameters. *Trichoderma* might secrete highly active chitinases which could affect egg hatching and larvae mortality by destroying chitin as the main component of the eggshell (Abdelatief and Bakr, 2018). *Trichoderma* spp. consider as plant growth and disease resistance bio-stimulants and inducer when colonizing the roots system (Yakhin *et al*., 2017 and Ramirez-Valdespino *et al*.,2019). Recorded higher root volume, plant height and leaf area in tomato plants treated with compost enriches with Trichoderma could be due to hormones production. The higher root volume indicates the ability to uptake of nutrients and water more easily which help in minimizing the nematode damage.

It is great worthy to mention here that the Trichoderma treated compost significantly suppressed the nematode populations in all concentrations compared with control or non-treated soils. Our results revealed that fewer numbers of second-stage juveniles could penetrate the tomato roots after staining with the Phloxine-B technique. It could be revealed that the inoculated compost with the Trichoderma to nematode-infested soil might enable the production of nematicides metabolites with anti-nematode activity such as those found in the compost extracts, which could immobilize J2 and thus reduce root-knot nematode penetration as we found in former studies (Salem and Mahdy,2015). Moreover, through this bio fumigated compost biofortified with this antagonistic biocontrol agent i.e., Trichoderma might directly parasitize the Root-knot nematodes in its all stages. The phytotoxicity of the highest rates of mix compost at the used high concentration treatment may be probably related to the high pH of this material (Arvanitoyannis and Kassaveti, 2007). Also, the phytotoxicity could be due to the accumulation a toxic concentration of heavy metals when d-using high dose of compost.

## CONCLUSION

According to our findings through this study, we can conclude that the biofumigation and biofortified compost with the biocontrol agents like *Trichoderma harizanum* is a promising, sustainable to induce plant growth chemically, physiologically, and morphologically to increase the normal resistance of plants against the pathogens and is therefore an alternative to chemical fumigation for sustainably suppressing root-knot nematode. The antagonistic compounds against RKN, developed in biofortified -treated compost play key roles to suppress plant parasitic nematodes by generating various antagonistic substances or activities. According to our findings through this study, we can conclude that a bio-moisturized and bio-enhanced organic fertilizer with biocontrol agents like *T. harizanum* is promising and sustainable to induce plant growth chemically, physiologically, and morphologically and is therefore an alternative to chemical fumigation to suppress root nematodes in a sustainably. Anti-RKN compounds, developed in the bio-enhanced fertilizer, play key roles in suppressing plant-parasitic nematodes by generating various antagonistic substances or activities.

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