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ORIGINAL RESEARCH

Controlling root-knot nematode *Meloidogyne incognita* in tomatoes using modified effective microorganisms-fermented plant extract and compost manure

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Abstract

Purpose Nematode diseases are major constraints in tomato production. Screenhouse and field experiments were conducted to assess the efficacy of Effective Microorganisms-Fermented Plant Extract (EM-FPE) and compost manure singly and in combination on *Meloidogyne incognita* infecting tomatoes.

Method Screenhouse and field experiments were designed respectively as 2×5 and 2×4 factorial fitted into a completely randomized design (CRD) in the screenhouse and randomized complete block design (RCBD) on the field. For single treatments, 100 ml of EM-FPE or 200 g of compost was used per plant while 50 ml of EM-FPE and 100 g of compost were combined and used per plant for treatment combination. Pots that did not receive any treatment served as control. Data were collected on growth parameters, fruit production, galling, and soil nematode population. The data collected was subjected to analysis of variance (ANOVA) where significant differences in means were separated using Fisher's Least Significance Difference (LSD) Test at $P = 0.05$.

Results In both trials, treated plants performed significantly better. No significant difference was recorded among the three treatments for soil nematode population and root galling on the field. But in the screenhouse trial, plants treated with the combination of EM-FPE and compost recorded higher soil nematode population (150) and root galling (7) at harvest but the plants performed well. Among the treatments, compost manure applied singly gave the best result with respect to vegetative growth, flower formation, and yield of the tomatoes.

Conclusion This study reveals that both treatments, EM-FPE, and compost manure could be relied on for effective control of *Meloidogyne incognita* in tomatoes.

Keywords *Solanum lycopersicum*, Vegetable, Pest, Gall, Screenhouse, Nigeria

Introduction

Tomato (*Solanum lycopersicum*) is a staple fruit vegetable, one of the most important vegetables worldwide. Tomato is the second most-produced vegetable crop around the world behind the potato crop (Abdullah et al. 2014). It accounted for about 60% of the global vegetable production at 177 million tonnes in 2016 (Rudolf 2018). Tomatoes are a well-known source of income and

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a major contributor towards food security. Apart from being an important food crop, tomato is an acknowledged model species for evolutionary studies and research on fruit developmental and metabolite accumulation (Takayuki and Alisdair 2015). Tomato is used as condiments for stew which is a regular feature of African meals and accounts for about 18% of the average daily consumption of vegetables in Nigeria (Ebimieowei and Ebideseghabofa 2013). Daily intake of tomatoes provides the body with nutrients like carotene, vitamin, lycopene which lower the risk of cancer and cardiovascular diseases (OKoh and Aluanya 2014). Nigeria is a great producer of the crop. In Africa, Nigeria is ranked second (after Egypt) largest producer of tomatoes and globally the 14th largest producer; its total production annually has been estimated to about 1.8 million metric tonnes (Eno-Abasi et al**.** 2018). However, tomato production, in Nigeria, and across the world faces several constraints including pests and diseases such as nematodes. Plant parasitic nematodes (PPNs) cause significant damage to almost all kinds of crops but due to their subterranean habit and microscopic size they remain invisible to the naked eye making them insidious pathogens that are overlooked (Izuogu et al. 2013; Ngangbam and Devi 2012). Current losses due to PPNs have been estimated up to the tune of US$358.24 billion annually on a worldwide basis, which is undoubtedly a serious threat to the world economy (Mahfouz et al. 2014). This is even likely to be a significant underestimate of the actual figure as many growers in developing nations are unaware of the existence of these plant-parasitic nematodes (Jones et al. 2013). *Meloidogyne* spp. are one of the most damaging PPNs. *Meloidogyne* species cause high levels of economic loss in a multitude of agricultural crops worldwide with dramatic yield losses being reported on vegetables. They damage plants roots by limiting their development and restricting their water and nutrients uptake ability (Izuogu and Abiri 2015). *Meloidogyne* species negatively affect both the quality and quantity of marketable yields of tomatoes by causing the reduction of fruits number and size. Next to direct losses due to nematode attacks, many indirect losses through loss of irrigation water and fertilizers can occur since damaged roots do not utilize water and fertilizer as efficiently as healthy roots. Besides, as nematode infection undermines resistance to other pests and diseases, it can directly lead to additional and inappropriate use of pesticides (James et al. 2010). The control of nematodes has long relied on chemical nematicides. But today, due to the increased cost, non-availability of the nematicides and their hazardous nature on human, animals, and the environment, and restrictions on their use, new management strategies are being investigated. Studies have shown positive effects of several plant extracts with nematicidal properties on different species of nematodes (Izuogu et al. 2016; Izuogu et al. 2013) as well as some microorganisms as bioagents against the same pests. Microorganisms such as Lactic Acid Bacteria (LAB) present in raw milk, Saccharomyces cerevisiae (yeasts) and photosynthetic bacteria have been studied and reported to be beneficial (Higa and Parr 1994). They complement each other and are in a mutually beneficial relationship with the roots of plants in the soil ecosystem thereby releasing substances such as hormones which are associated with suppression of plant pathogens. Various soil amendments including compost have also been reported in the control of plant parasitic nematodes (Oka et al. 2007).

Cattle and poultry manure, neem, grasses, ash and cattle urine are known to release nitrogen in composts, and the efficacy of compost against nematodes increases as %N in amendments increases. This study therefore aimed at evaluating the controlling effect of compost manure and EM-Fermented Plant Extract on *Meloidogyne incognita* infecting tomatoes under screenhouse and field conditions.

Materials and methods

Location of the experiments

The study was conducted at the University of Ilorin, Ilorin, Kwara State, Nigeria. The pot experiment was carried out in the screenhouse of the Department of Crop Protection, Faculty of Agriculture, University of Ilorin, and the field experiment was conducted at the University of Ilorin Teaching and Research Farm (8" 29N, 43"5E), located within the Southern Guinea Savannah Zone, Nigeria.

Sources of materials

The materials used for the compost preparation comprised: cow dung, poultry manure, cattle urine, weeds, grasses and ash while raw milk, molasses, yeast and weeds (*Azadiracta indica, Chromolaenaodorata, Hyptis suaveolens, Morinda lucida, Moringa oleifera, Piliostigma thoningii, fluegga virosa)* were used for the EM-EM-FPE. All these materials were obtained from different locations within Ilorin town.

Tomato Seeds

Two varieties of tomatoes (Roma VF and Tomato-82-B) seeds were purchased from a registered Agro-chemical shop within Ilorin, Kwara State, Nigeria.

Root-knot nematodes (eggs and juveniles)

Roots of *Celosia argentea* plants severely galled were collected from an established nematode culture from which eggs and juveniles of *Meloidogyne incognita* were extracted.

Determination of initial nematode population (eggs and juveniles)

The galled roots were gently and properly washed under tap in order to get rid of attached soil. These were then cut into small pieces. Eggs were extracted from the chopped galled roots by agitating in 5% NaOCl for 2 to 3 min in a Kilner's jar (Hussey and Barker 1973). The eggs were thoroughly rinsed with tap water on nested 150- and 25-µm-pore sieves and collected into a beaker. The extract was allowed to settle and the supernatant was decanted leaving the suspension containing the eggs. The *Meloidogyne incognita* eggs were counted under a compound microscope. The juveniles were extracted using the modified Baermann's method of extraction. At the end, an approximate population density of 375 juveniles and 2072 eggs were obtained respectively from two different samples of 5 g of the *Celosia agentea* galled roots which was used for inoculation in the screenhouse. In other words, every experimental pot, except the control pots received 5g of galled roots containing 375juveniles and 2072 eggs of *M. incognita.* For the field trial, soil samples were collected across the plots on the field in a zig-zag pattern and mixed to form a composite sample. The soil samples were taken to the department of Crop Protection Laboratory where nematode extraction was carried out using the modified Baermann's method. To confirm the presence of nematodes, some of the samples were sent to the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria. The analysis of the soil samples revealed that approximately 300 juveniles of *Meloidogyne incognita* were found in 100 ml of the soil sample.

Compost preparation

Both fresh and brown forms of neem leave (*Azadiracta indica)* and grasses (*Penisitum purpurum* and *Panicum maximum*) were used. Two sacks of 50 kg of cow dung, 2 sacks of 50 kg of poultry manure, 5 kg of ash and 5 litters of cattle urine (ratio one part of each category of material to the other). The composting was done on a

flat surface. The process of the preparation is as follows. A certain quantity of the weeds was laid on the ground at first and the rest of the materials added accordingly in the following order: cow dung, poultry dung, ash, urine, and water. This process was repeated until the whole material was completely used. At the end, a pile of about 60 cm high from the ground was formed. It was covered with an ethylene bag and was left for two months. The pile, using shovel was being turned every two days from the second week, for the two months until the composting was completed.

EM-fermented plant extract preparation (EM-FPE)

Effective microorganisms (EM) comprise of about 80 species including photosynthetic bacteria, lactic acid bacteria, yeasts, actinomycetes, and fermenting fungi such as Aspergillus and Penicillium. Various forms of EM are known today. They include Fermented Plant Extracts, most commonly done as a plain liquid manure or plant extract. So the weeds were chopped into small pieces and filled into a 150 L size drum placed at the room corner of the laboratory to avoid sunlight. In a separate container, molasses (2 L), liquid milk (2 L) and yeast (2 L) were mixed together and afterward, the mixture was poured over the weeds inside the drum. Tap water was added, filling the drum all the way to the top. The drum was sealed with an airtight lid with a perforation for passage of a small hose pipe that was channeled into a transparent plastic bottle filled up to three quarter with distilled water. This served the purpose of checking the fermentation process by appearance of bubbles inside the water. The whole material was allowed to ferment for a period of three weeks. At the end of the experiment, when there was no observable gas bubbling in the water, the liquid from the drum was strained off into another container. The strained liquid was the Fermented Plant Extract which served as one of the treatments.

Screenhouse experiment

Soil sterilization and experimental layout

Sandy-loam soil was collected from a fallow land around the screenhouse of the Department of Crop Protection, Faculty of Agriculture, University of Ilorin. Using the method described by Gautam and Goswami (2002), the soil was sterilized in a drum at 60 ºC for twenty-four hours. It was allowed to sufficiently cool for 72 hours before filling up 12 litters size buckets (50), perforated at the bottom and placed on an elevated platform to avoid reinfestation of soil by microorganisms. The experimental design was a factorial type (variety and treatment) fitted in a completely randomized design, replicated five times.

Planting and management

The tomato seedlings were raised in nursery in sterilized top soil in plastic buckets for three weeks. The seedlings were transplanted into the buckets filled with sterilized soil. Two seedlings were transplanted in each buckets initially but later thinned to one vigorous seedling per pot. The buckets were randomly arranged and labelled.

Inoculation of root-knot nematode

Chopped root galls of *celosia argente a* were inoculated in the pots at the rate of 5 g per pot (bucket) immediately after transplanting to ensure that the juveniles meet with the susceptible stage of the tomato plants.

Treatments application

One hundred ml (100 ml) of the EM-FPE solution and 200 g of the compost was applied each to the tomato plant for the single application at ratio of Fifty ml (50

ml) of EM-FPE solution and 100 g of compost for the combination. Each treatment was replicated five times for each variety. Five pots were inoculated without treatment for each variety, they served as negative control while other five pots for each variety as well were neither inoculated nor treated and served as positive control. The treatment was applied twice: at planting and two weeks after planting.

Field experiment Experimental design

The field was a naturally *Meloidogyne incognita* infested soil. The initial nematode population per 100 ml of soil was 300 juveniles. The experiment was a 2×4 factorial fitted into a Randomized Complete Block Design (RCBD) and replicated three times.

Layout

The field, which was a well-drained coarse sandy-loam, was ploughed, harrowed, and ridged. The field area was 15 m × 24 m with plot size of 2 m ×4 m, with spacing of 1 m between blocks and 0.5 m between plots.

Transplanting of seedlings

The seedlings were transplanted after 3 weeks at the nursery at the rate of 2 to 3 seedlings per stand with a distance of 0.6 m between stands and later thinned to one seedling per stand.

Treatments application

The treatments were applied following the procedure as described for the screenhouse experiment except that there was no positive control as the whole field was naturally infested with *M. incognita*.

Data collection

The data collected included: plant height, the number of leaves, number of fruits, fruit weight, root and soil nematode populations, number of galls and root gall index.

Root gall rating

The root galling index was assessed on a scale 0-10 as described by Bridge and Page (1980).

Data analysis

All numerical data obtained were subjected to two-way analysis of variance (ANOVA) using the International Business Machine Genstat version 17 where significant means were separated using the Fishers Least Significance Difference (LSD) Tests at a 5% level of significance.

Results and discussion

Significant differences in the growth and yield were recorded between the treated and the untreated plants. Generally, all the treated plants performed significantly better than the untreated plants with respect to their height and number of leaves. Amongst the treatments, the maximum growth (Tables 1, 2, 3, and 4) and yield (Tables 5 and 6) were recorded in the plant treated with solo compost. The least growth and yield were recorded among the plants treated with solo E.M.-FPE while the plants treated with the combination of the two came in between.

Table 1 Effect of treatment on the height of *Meloidogyne incognita* infested tomato plants under field conditions

	Weeks After Transplanting							
Treatments	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
EM-FPE	10.73	15.00^{ab}	18.5^{ab}	26.45^{b}	35.13^{b}	46.36^{b}	57.25^{b}	68.83^{b}
Compost	10.20	13.33^{bc}	22.47^{a}	41.13^{a}	49.48^{a}	61.82^{a}	70.39^{a}	81.88^{a}
EM + Comp	9.45	16.67^{a}	22.50^{a}	30.00^{b}	40.85^{b}	57.15^{b}	69.03^{a}	79.31^{a}
Control	10.00	12.33^{c}	15.67^{b}	18.83^{c}	23.12^{c}	28.17^{c}	40.22^{c}	50.50^{c}
SEM	0.50	0.64	1.47	1.33	1.89	2.76	2.17	2.77
	NS							

Each value is a mean of three replicates. The figures with the same letter in the same column are not significantly different using Fishers Least Significant Difference Test (LSD) at P=0.05.
EM-FPE= Effective Microorganisms-Fermented Plant Extract
EM + comp= EM-FPE + compost.
NS = Non significant
SEM = Standard Error of the means

Table 2 Effect of treatment on the height of *Meloidogyne incognita* infected tomato plants under screenhouse conditions

	Weeks After Transplanting							
Treatments	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
EM-FPE	8.65	10.56^{a}	20.30^{b}	29.80^{b}	42.94^{c}	55.20^{b}	63.90^{b}	75.30^{ab}
Compost	8.15	10.20^{a}	21.50^{ab}	38.85^{ab}	57.44^{ab}	70.40^{a}	81.30^{a}	89.50^{a}
EM+Comp	8.72	10.95^{a}	26.40^{a}	44.90^{a}	65.09^{a}	78.50^{a}	87.00^{a}	90.70^{a}
Positive C	8.93	10.80^{a}	21.10^{b}	32.75^{b}	48.35^{bc}	55.00^{b}	64.90^{b}	72.05^{b}
Negative C	8.54	8.80^{a}	13.60^{c}	17.80^{c}	20.20^{d}	25.90^{c}	30.50^{c}	33.60^{c}
SEM	0.56	0.80	1.80	3.25	4.63	5.16	5.62	5.84
	NS							

Each value is a mean of five replicates. The figures with the same letter in the same column are not significantly different using Fishers Least Significant Difference Test (LSD) at P=0.05.
EM-FPE = Effective Microorganisms-Fermented Plant Extract
EM + comp = EM-FPE +compost.
Positive C= positive control: pot not inoculated
Negative C = negative control: pot inoculated with *Meloidogyne incognita* but not treated
NS = Non significant
SEM=Standard Error of the means.

Table 3 Effect of treatment on the mean number of leaves of *Meloidogyne incognita* infested tomato plants under field conditions

	Weeks After Transplanting							
Treatments	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
EM-FPE	3.17^{ab}	5.17^{a}	7.33^{a}	12.67^{b}	18.50^{b}	23.50^{b}	35.83^{b}	46.33^{b}
Compost	3.00^{b}	4.83^{a}	7.33^{a}	19.17^{a}	31.67^{a}	47.67^{a}	63.33^{a}	77.00^{a}
EM+comp	3.50^{a}	4.50^{ab}	7.00^{a}	14.33^{b}	24.67^{ab}	46.50^{a}	53.50^{a}	65.00^{a}
Control	3.16^{ab}	4.83^{b}	4.17^{b}	7.83^{c}	10.67^{c}	14.83^{c}	18.00^{c}	24.17^{c}
SEM	0.16	0.31	0.46	1.14	2.35	2.76	3.90	5.04

Each value is a mean of three replicates. The figures with the same letter in the same column are not significantly different using Fishers Least Significant Difference Test (LSD) at P=0.05.
EM+comp= EM-FPE +compost.
SEM=Standard Error of the means

Table 4 Effect of treatment on the mean number of leaves of *Meloidogyne incognita* infected tomato plants under screenhouse conditions

	Weeks After Transplanting							
Treatments	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
EM-FPE	3.30	4.90	7.30^{ab}	9.10^{b}	10.70^{b}	14.00^{bc}	15.90^{ab}	18.80^{ab}
Compost	3.20	5.30	8.00^{ab}	11.60^{a}	13.50^{a}	17.00^{ab}	19.30^{a}	21.90a
EM+Comp	3.00	5.20	9.00^{a}	11.40^{a}	14.40^{a}	17.10^{a}	18.70^{a}	21.70^{a}
Positive C	3.20	4.80	7.00^{b}	8.40^{bc}	10.00^{b}	12.80^{c}	13.70^{b}	16.20^{b}
Negative C	3.20	4.40	6.20^{b}	6.90^{c}	7.20^{c}	7.50^{d}	9.60^{c}	9.40^{c}
SEM	0.13	0.37	0.64	0.71	0.93	1.08	1.25	1.45
	NS	NS						

Each value is a mean of five replicates. The figures with the same letter in the same column are not significantly different using Fishers Least Significant Difference Test (LSD) at P=0.05.
EM + comp = EM-FPE +compost.
Positive C = positive control: pot not inoculated
Negative C = negative control: pot inoculated with *Meloidogyne incognita* but not treated
SEM=Standard Error of the means
NS = Non significant

Table 5 Effect of treatment on the number of fruits and the fruit weight of tomato plants infected with *Meloidogyne incognita* under field conditions

Treatments	**Number of fruit per plant**	**Number of fruit per plot**	**Fruit weight (g) per plot**
EM-FPE	16.67^{b}	86.2^{b}	2140^{b}
Compost	30.67^{a}	168.5^{a}	3133^{a}
EM+Comp	22.50^{b}	112.8^{b}	2370^{b}
Control	8.83^{c}	40.2^{c}	896^{c}
SEM	2.11	12.18	202.2

Each value is a mean of three replicates. The figures with the same letter in the same column are not significantly different using Fishers Least Significant Difference Test (LSD) at P=0.05
EM + comp= EM-FPE + Compost
SEM = Standard Error of the means

The analysis of the results with respect to root and soil nematode population at harvest showed that there was significant difference only between the treated tomato plants and the untreated ones. The treatments equally suppressed the build-up of *Meloidogyne incognita* population in both soil and roots of the tomato plants hence, they performed better. The untreated plants however, recorded an overwhelming population of the nematode which led to stunted growth and even death of some plants on the field and in the screenhouse trials (Tables 7 and 8; Fig. 1 and 2). No significant difference was recorded among the three different treatments.

Table 6 Effect of treatment on the number of fruits and the fruit weight of tomato plants infected with *Meloidogyne incognita* under screenhouse conditions

Treatments	**Number of fruits per plant**	**Fruit weight (g) per plant**
EM-FPE	4.20^{b}	74.95^{b}
Compost	7.30^{a}	101.59^{a}
EM+Comp	4.60^{b}	77.70^{b}
Positive C	1.70^{c}	26.88^{b}
Negative C	0.00^{d}	0.00^{d}
SEM	0.45	9.15

Each value is a mean of five replicates. The figures with the same letter in the same column are not significantly different using Fishers Least Significant Difference Test (LSD) at P=0.05; EM + comp = EM-FPE + Compost; Positive C = positive control: pot not inoculated; Negative C = negative control: pot inoculated but not treated.
SEM = Standard Error of the means

Table 7 Effect of treatment on soil and root populations of *Meloidogyne incognita* in the rhizosphere of tomato plants under field conditions

Treatments	Initial Mean Pop of *M. incognita*	Soil pop of *M. incognita* at harvest	Root pop of *M. incognita* at harvest	No of galls	Galling index
EM-FPE	300	93.30[a]	71.7[a]	29.67[b]	3
Compost	300	99.70[a]	78.3[a]	16.17[a]	2
EM+ Comp	300	76.50[a]	86.2[a]	16.83[a]	2
Control	300	695.00[b]	767.3[b]	75.50[c]	7
SEM		9.02	8.72	3.56	

Each value is a mean of three replicates. The figures with the same letter in the same column are not significantly different using Fishers Least Significant Difference Test (LSD) at P=0.05; EM + comp = EM-FPE + Compost
SEM = Standard Error of the means

Table 8 Effect of treatment on soil and root populations of *Meloidogyne incognita* in the rhizosphere of tomato plants under screenhouse conditions

Treatments	Initial Pop of *M. incognita*	Soil pop of *M. incognita* at harvest	Root pop of *M. incognita* at harvest	No of galls	Galling index
EM-FPE	375juveniles +2072 eggs	150.00[a]	99.20[c]	2 6.50[b]	3
Compost	375 juveniles +2072 eggs	127.50[a]	54.70[b]	20.00[b]	2
EM + Comp	375 juveniles +2072 eggs	131.20[a]	150.20[d]	24.30[b]	7
Positive C	0.00juveniles +0000 eggs	0.00[a]	0.00[a]	0.00[a]	00
Negative C	375juveniles +2072 eggs	1183.70[b]	1117.70[e]	87.20[c]	8
SEM		58.20	3.55	6.71	

Each value is a mean of three replicates in field and five replicates in screenhouse. The figures with the same letter in the same column are not significantly different using Fishers Least Significant Difference Test (LSD) at P=0.05
EM + comp= EM-FPE + Compost; Positive C= positive control: pot not inoculated
Negative C = negative control: pot inoculated with *Meloidogyne incognita* but not treated.
SEM = Standard Error of the means.

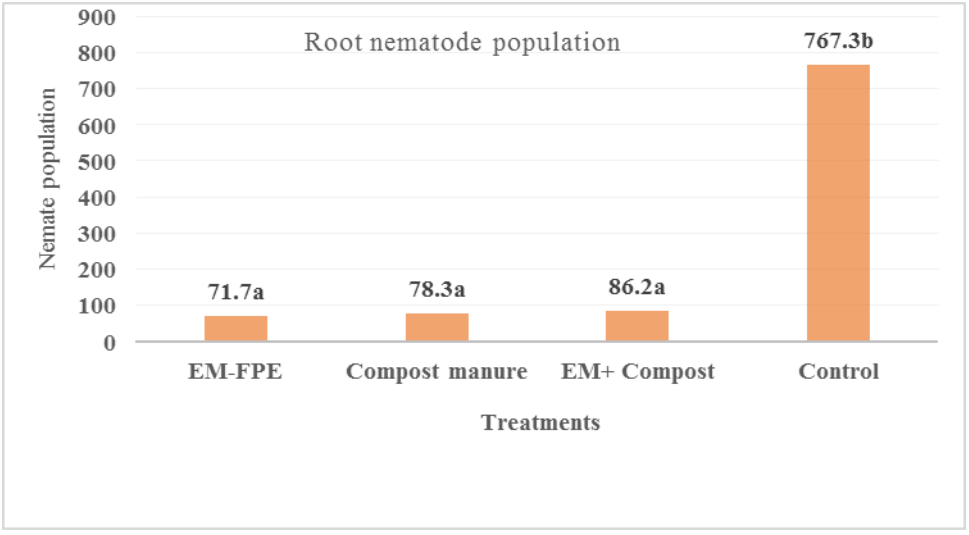

Fig. 1 Effect of treatments on the root population of *Meloidogyne incognita* in the tomato plants under field conditions at harvest

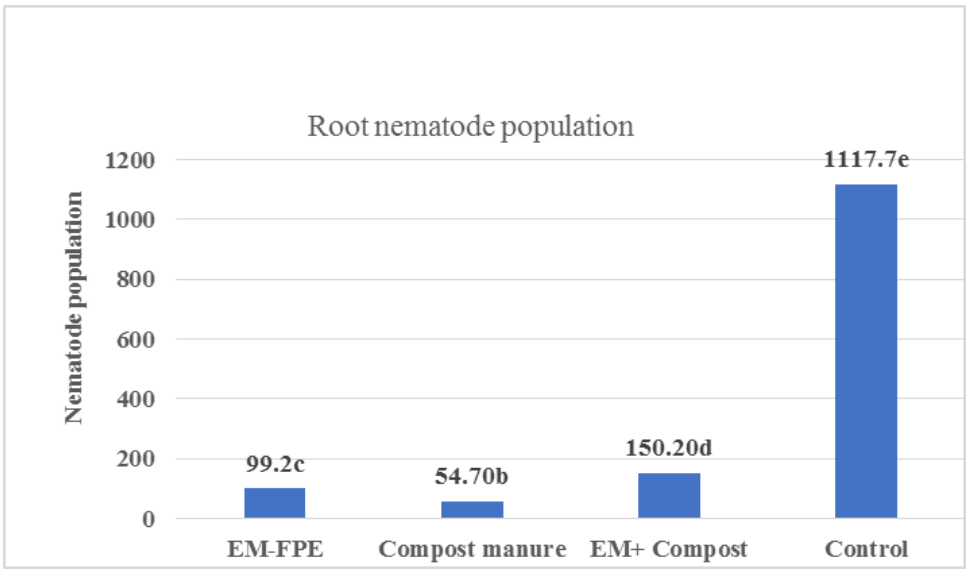

Fig. 2 Effect of treatments on root population of *Meloidogyne incognita* in the tomato plants under screenhouse conditions at harvest

Compost is known to boost plant growth (Rady et al. 2016). However, when confronted to constraints like nematode diseases, the boosting effect is restricted, since root-knot nematodes damage plants roots by limiting their development and restricting their water and nutrients uptake ability (Izuogu and Abiri 2015). The tomato plants might have been able to perform significantly well because of the nematicidal properties of the compost. The materials used for the composting are known to release nitrogen compounds which favor the growth of beneficial microorganisms that antagonize plant parasitic nematodes in the soil. This collaborates the report of a study by Thoden et al. (2011), and Oka (2010) that many plant residues and other amendments could release nitrogen compounds, organic acids, or other compounds that may have adverse effects on nematodes. De Jin et al. (2005) reported that compost contains chitinolytic bacteria producing enzymes like chitinase, that can suppress plant parasitic-nematodes thereby reducing their population. Similarly, the EM-FPE showed significant effect on the suppression of the nematode population compared to the controls. The microorganisms in the effective microorganisms could include Lactic Acid Bacteria (LAB), Saccharomyces and photosynthetic bacteria. These microorganisms have been studied and reported to be able to release organic acids which have adverse effect on nematodes. Lactic acid bacteria in particular secrete lactic acid, a strong sterilizing compound which check, and suppress the population of harmful organisms such as nematodes in the soil thereby creating a favorable environment to the growth of plants. This agrees with the report by (Himangini et al. 2019), that lactic acid produced by lactic acid bacteria has sterilizing effects and its presence in the soil may check the proliferation of nematode population and offer protection against nematode associated plant diseases.

The combination of compost with the EM-FPE also showed positive effect against nematode proliferation. The integration of different control measures might have better controlling effect on nematodes. Even though the solo compost was the best treatment based on the results, an interesting aspect of the combination was observed. The optimal performance of the plants in spite of the presence of high nematode population (150, in the screenhouse) showed that the combination of the two control measures could enhance plant tolerance to nematodes.

Conclusion

Meloidogyne species contribute to huge losses in tomato production. Compost and EM fermented plant extract are effective measures of control for minimizing the loss incurred according to this study. Therefore, compost and its combination with EM-Fermented Plant Extract, hold a good promise in sustainable agriculture as effective and cheap strategies in the management of root-knot nematodes infecting tomatoes.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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