Research Article

# Susceptibility of Sweet Potato Varieties to *Meloidogyne incognita* and Use of Effective Microorganisms and Compost Manure for the Disease Management

**Aishat Adetola Anifowose*, Nkechi Betsy Izuogu and Benoit Katchitche Sossou**

*Department of Crop Protection, University of Ilorin, PMB 1515, Ilorin, KW 240003, Nigeria*

**Abstract** | To address the constraints posed by root-knot nematodes (RKN) and hazards of chemical nematicides in sweet potato production, effective microorganisms (EM) and compost manure were applied singly and in combination on two varieties of sweet potato under field and -screenhouse conditions. The trials were 2x5 (screenhouse) and 2x4 (field) factorial experiments fitted into a randomized complete block design (RCBD), respectively, and the field was naturally infested. Each pot in the screenhouse was inoculated with 2400 *M. incognita* juveniles at planting. Compost manure was incorporated a week before planting at 1.5 t/ha for the single treatments and at 0.75 t/ha at planting for the combined treatments. EM was applied twice at a two-weeks interval at 4000 l/ha and 2000 l/ha for the single and combined treatments, respectively. The nematode-inoculated, untreated pots and plots served as negative controls. Generally, the increase in growth and yield parameters and decrease in nematode population was significantly higher (P=0.05) in treated plants than in control plants. Galling was most severe in negative control plants with poor yield. Even so, the yellow jersey variety was more susceptible to *Meloidogyne incognita* infection. However, the combination of EM and compost manure had significantly higher performance than the other treatments, especially on the Boniato variety. The implications of EM combined with compost manure as eco-friendly control of RKN infection in sweet potatoes in a changing climate are noteworthy and should further be tested and favourably considered for use by the potatoes farmers for adoption.

**Received** | June 25, 2023; **Accepted** | October 22, 2023; **Published** | November 15, 2023
***Correspondence** | Aishat Adetola Anifowose, Department of Crop Protection, University of Ilorin, PMB 1515, Ilorin, KW 240003, Nigeria; **Email:** imanmytreasure@gmail.com
**Citation** | Anifowose, A.A., Izuogu, N.B. and Sossou, B.K., 2023. Susceptibility of sweet potato varieties to *Meloidogyne incognita* and use of effective microorganisms and compost manure for the disease management. *Pakistan Journal of Nematology*, 41(2): 135-143.
**DOI** | https://dx.doi.org/10.17582/journal.pjn/2023/41.2.135.143
**Keywords** | Plant-parasitic nematodes, *Ipomea batatas,* Infection, Yield losses, Bio-control microbial inoculant, Fermentation



## Introduction

Sweet potato (*Ipomea batatas* (L.) Lam) is an important crop, especially in Africa and Asia, where its high beta-carotene content helps to preserve vision and immunity (Ukpabio *et al.*, 2012). Elsewhere, culinary products from sweet potatoes include; pies, pancakes, sweet desserts, potato balls, porridge, stew, caramelized chunks, buns, etc. (Thaler and Safferstein, 2014). It recently found use in the clothing industry

due to the abundance of anthocyanins in the purple sweet potatoes. The extracted purple sweet potato natural colorant was used to dye leather, silk, and cotton fabrics in an eco-friendly approach (Velmurugan, 2017). However, supply of this sweet tasting tuber is scarce, with Nigeria producing only 3.7% of the global production of 89.5 million tonnes (FAOSTAT, 2020). This is partly due to the 25% loss in sweet potatoes attributed to RKN found in hot climates and short winter areas (Overstreet, 2009). Root galls on sweet potatoes drain the plant's photosynthates and nutrients (Moens *et al*., 2009), cause deformations and blemishes, and make tuber unmarketable and susceptible to secondary infections (Onyeka *et al*., 2013).

Earlier, control of this infamy had been achieved through the use of very expensive and hazardous chemicals. Hence, the need for alternatives those are cheap and environmentally friendly.

Globally, effective microorganisms (bio-control microbial inoculants) have been found to be promising in preventing and restraining pests through the introduction of beneficial microorganisms, mainly photosynthetic bacteria, lactic acid bacteria and yeasts to soils and plants (Hu and Qi, 2013). EM produce antioxidants, which modify treated soils to become disease-suppressive (Higa and Jame, 1994). The climate is changing, yet the human population continues to increase, especially in the tropics, where species are least adaptable to the impacts of climate change. Hence, the need for the existing agricultural production systems to be intensified by means other than synthetic pesticides and chemical fertilizers (Precision Reports, 2023).

Many soil-borne plant pathogens and the diseases they cause have been suppressed with the use of compost manure with varying levels of success (Atungwu *et al*., 2009). The organic matter provided in compost manure provides food for microorganisms, which keeps the soil in healthy, fertile, and balanced conditions (Sossou *et al*., 2022). The resulting increase in the microbial diversity of soil and plant ecosystems creates a healthy soil ecology that has the ability to offer defenses to plants against soil associated diseases caused by pathogenic microorganisms and parasites (Sossou *et al*., 2022). Thus, we hypothesized the efficacy of compost manure and EM in the management of *Meloidogyne incognita* infection in sweet potatoes. We evaluated and compared two sweet potato varieties for susceptibility to *M. incognita,* and determined the effects of compost manure and EM applied singly and in combination on the growth and yield parameters of sweet potato plants on the one hand; and on the final nematode population and gall rating on the other.

## Materials and Methods

*Location of the experiments*

The pot experiment was conducted at the Department of Crop Protection's screenhouse, while the field experiment was conducted at the Teaching and Research Farm of the Faculty of Agriculture, University of Ilorin (8°29' N and 4°35' E), located at 320 m above sea level in the Southern Guinea Savannah Zone with annual precipitation of 1000 – 1200 mm (Koppen-Geiger Classification Aw), Nigeria, between June 2018 and July 2019.

*Preparation of treatments*

**Preparation of compost manure:** Fifty (50) kg of compost manure were prepared using: 300 kg of chicken droppings, 100 kg of cattle dung, 20 kg of neem leaf, 5 kg of leguminous weeds (*Crotalaria retusa* and *Mimosa pudica),* 2 kg of Ash, 1 kg of grass clippings (*Panicum maximum* and *Penisitum purpurum*), 5 L of cow and human urine, and Water. All were obtained from the Ilorin metropolis.

**Procedure:** A level area at the back of the Department of Crop Protection's screenhouse was used. A 3-inch layer of carbon rich materials (neem leaf and fresh grass clippings) was spread on the 5184 square inches area, the two inches of nitrogen source (chicken droppings, cattle dung and leguminous weeds) were spread on top of it. Then layering was continued using three inches of carbon-rich materials and two inches of nitrogen source until the pile was 4 feet tall. The pile was being wet with urine, ash and water as building continued to make it slightly damp all the way through. It was then covered with a polyethylene material in order to prevent nutrient leaching and contamination and also to secure the compost pile from rain. The pile was kept moist but not soggy and turned every two days. The temperature of the center of the pile was recorded during every turn. The first temperature recorded was 52°C and it kept increasing (as high as 62°C), but not more than that as turning continued for the composting period of about four months. The compost manure was then used when it

stopped heating in the center and was dark brown, crumbly, and had an earthy smell (almost like black soil); at this point, it had a room temperature of 26°C.

**Preparation of effective microorganisms:** A 120 L capacity air-tight bucket was used to prepare 60 L of mixture comprising 2 L fresh milk, 40 L water, 2 L molasses, 200 g yeast, 8 kg brown weed leaves, and 2 kg green weed leaves. The weeds used were *Hyptis suaveolens*, *Chromolaena odorata*, *Moringa oleifera*, *Azadirachta indica*, *Flueggu virosa* and *Tithonia diversifolia*. All materials were obtained from the Ilorin metropolis at the Gaa Imam area, the Oja tuntun area, and the University of Ilorin farms.

**Procedure:** The dry materials (shredded leaves of brown or dry weeds, and green or fresh weeds) were mixed together in the 120-capacity air-tight container with an airlock. One litre of warm water was used to mix the fresh milk, yeast and molasses together in a 10 L container. The wet mixture in the 10 L container was then mixed together with the dry materials in the 120 L bucket capacity immediately to prevent the fresh milk from curdling. Water was added to the mixture and almost filled the container, leaving 10 L of space for aeration. The container was tightly covered, and fermentation was allowed until it was completely done (1 month) in the Biotechnology Laboratory of the Department of Crop Protection. The mixture was stirred every two days and the temperature monitored throughout the fermentation period (Higa, 1991; TeraGanix, 2015).

*Source of vines*

Two varieties of sweet potatoes (Boniato and Yellow jersey) were obtained from the Kwara State Ministry of Agriculture and Natural Resources, Offa Area Office, Kwara State.

*Screenhouse experiment*

Sandy-loam soil obtained from around the screenhouse of the Department of Crop Protection was steam sterilized using the barrel steam sterilizarion method at 180°F for 24 hours with firewood as the source of heat and was all used to fill 10 L plastic buckets perforated at the bottom to improve drainage. The sterilized soil was left for 72 hours to cool and reconstitute its components before planting vine cuttings of each sweet potato variety in to it (Gautam and Goswami, 2002). The screenhouse experimental design was a 2x5 factorial experiment in a randomized complete block design with five replicates. The two factors tested were: varieties at two levels (Boniato and Yellow jersey) and treatment at five levels (effective microorganisms, compost manure, effective microorganisms + compost manure, negative control and positive control).

**Source of inoculum:** Roots of *Meloidogyne incognita* infected *Celosia argentea* plants were obtained from the Asunlope area, Ilorin, Kwara State (Figure 1).

**Figure 1:** *Galled roots with RKN of Celosia argentea plants.*

Ten kilograms of roots of *Meloidogyne incognita* infected *Celosia argentea* plants were carefully washed to remove adhering soil particles and then cut into small pieces; the galls were excised from the roots, and then placed on a petri dish containing 20 ml of distilled water to moisten the galls. The eggs were extracted using the hypochlorite method described by Hussey and Baker (1973), and juveniles were extracted using the modified Baermann tray extraction method described by Barker (1985).

**Planting of vines:** One vine (20 cm) with a maximum of two nodes was planted into each bucket at 3 cm depth with a spacing of 1 m between blocks and 0.5

m within blocks.

**Nematode incorporation into the soil:** Four (4) replicates of each variety (8 pots per block) were inoculated with 2075 eggs and 325 *M. incognita* juveniles at planting. The pots inoculated with *M. incognita* juveniles were effective microorganisms, compost manure, effective microorganisms + compost manure, and negative control pots.

**Application of treatments:** For the single treatment, compost manure was incorporated a week before planting at a rate of 1.5 t/ha. While, effective microorganisms were applied at planting at a rate of 4,000 l/ha.

For the combined treatment, compost manure was incorporated at planting at a rate of 0.75 t/ha with the effective microorganisms which were applied at a rate of 2,000 l/ha.

Three out of the four replicates inoculated with *M. incognita* juveniles (above) (6 pots per block) were treated with 100 ml of effective microorganisms, 200 g of compost manure, and 50 ml of effective microorganisms + 100g of compost manure, respectively. The treatments were banded two inches to the side and two inches deeper than the plants in order to provide the plants with a concentrated zone of nutrients and improve nutrient use efficiency.

The nematode-inoculated untreated pots served as negative controls, and the uninoculated untreated pots served as positive controls.

The soil was regularly and carefully turned during the experiment to prevent it from compacting. Watering, earthing up, and weeding were also maintained.

*Field experiment*

Two vines (20 cm each) with a maximum of two nodes per vine were planted into each 30 cm ridge at 3 cm depth with spacing of 1m within the ridge x 0.5m between the ridges on a field size of 12m x15m. The field experimental design was a 2x4 factorial experiment in a randomized complete block design (RCBD) with three replicates. The field was naturally infested by *M. incognita,* but the initial soil nematode population was estimated to be 325 juveniles per 1 kg of soil before planting and the application of treatments to the soil. Treatments were applied as in the screenhouse, and cultural practices were maintained.

*Data collection*

Susceptibility to *Meloidogyne incognita* was determined by the root knot index, where the roots were examined and rated for galling responses on a gall scaling chart (0-10) as described by Bridge and Page (1980). The mean nematode population was determined. Furthermore, the host efficiency (reproduction factor (R.F.) was calculated, as R.F. = Pf/Pi, with Pf being the final population in root and soil samples and Pi being the initial inoculum (Afolami *et al.*, 2004)

Effects of treatment, and interaction between treatment and variety were determined by data recorded on growth and yield parameters, vine length, number of tubers, weight of tubers, etc.

*Data analysis*

All numerical data were subjected to a two-way analysis of variance (ANOVA) using the International Business Machine SPSS Statistics version 20, and where significant, means were separated using the Duncan's Multiple Range Test at a 5% level of significance

## Results and Discussion

The effect of treatment and variety was significant for all parameters. Treatment 3 (effective microorganisms + compost manure) with variety 1 (boniato) performed significantly higher (p=0.5) than with variety 2 (yellow jersey) and their controls (Tables 1 and 2). The same trend was observed for yield parameters (Tables 3 and 4). The treatment effect was significantly different (p=0.5), for all parameters and followed the same trends as in treatment with variety (Tables 5, 6, 7, 8).

The treated plants had a significantly lower final nematode population than control plants p = 0.5 (Tables 9 and 10).

The results of both screenhouse and field trials are shown in Tables 1-10:

The results obtained showed that the treatments tested: effective microorganisms applied singly, compost manure applied singly, and a combination of EM and compost manure; on the Boniato and Yellow jersey

**Table 1:** *The effect of treatment and variety on mean vine length (cm) of Ipomea batatas infected with Meloidogyne incognita in the screenhouse.*

| Treatments | WAP | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| V1T1 | 5.60ab | 52.00b | 118.00c | 184.20b | 188.80b | 294.80c | 330.60c | 316.80c | 303.80c |
| V1T2 | 7.80a | 68.20a | 175.40b | 254.40ab | 298.60a | 390.80b | 465.20b | 450.80b | 437.20b |
| V1T3 | 3.20bc | 73.00a | 209.20a | 302.00a | 347.80a | 525.60a | 568.20a | 553.80a | 543.70a |
| V2T1 | 5.60ab | 28.40c | 65.00d | 78.60c | 81.60c | 95.20d | 138.80d | 131.40d | 124.80d |
| V2T2 | 4.00bc | 11.20de | 36.80f | 50.60c | 50.2c | 62.40def | 74.30edg | 69.00de | 63.24efg |
| V2T3 | 4.00bc | 15.40cde | 49.00e | 50.40c | 64.20c | 78.20de | 90.80def | 84.60def | 80.40def |
| V1C- | 3.20bc | 11.40de | 14.00g | 66.6c | 18.20c | 28.20ed | 34.40fd | 29.20fg | 20.40fg |
| V1C+ | 4.00bc | 23.8cd | 35.20f | 51.6c | 75.80c | 98.80d | 131.40de | 113.6de | 105.80de |
| V2C- | 1.40c | 2.20e | 5.60g | 19.80c | 10.20c | 12.80f | 15.80g | 10.20g | 5.80g |
| V2C+ | 2.20c | 7.20e | 11.60g | 16.00c | 21.80c | 30.80ef | 35.60fg | 24.80fg | 20.60fg |
| S.E | 1.0 | 3.70 | 4.30 | 33.75 | 30.80 | 18.70 | 19.80 | 19.50 | 19.60 |

*Key: Means with the same letter(s) down the column are not significantly different at P= 0.05; WAP: weeks after planting; TRT 1: effective microorganisms; TRT 2: compost manure; TRT 3: effective microorganisms + compost manure; V1: Boniato; V2: Yellow jersey; S.E: Standard Error; C+: positive control;C–: negative control*

**Table 2:** *The effect of treatment and variety on the mean vine length of Ipomea batatas naturally infested by Meloidogyne incognita on the field per plant per week (cm).*

| Treatments | WAP | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| V1T1 | 10.10 | 78.50b | 139.33a | 230.80a | 884.40b | 1257.00c | 1739.70c | 1678.20c | 1606.33c |
| V1T2 | 9.90 | 78.20b | 134.90a | 229.70a | 854.33b | 1570.80b | 2006.80b | 1928.50b | 1894.20b |
| V1T3 | 10.90 | 109.50a | 207.40a | 303.90a | 1353.80a | 1893.20a | 2307.50a | 2222.80a | 2140.30a |
| V2T1 | 7.43 | 64.30bc | 148.33a | 219.33a | 797.77b | 1115.77cd | 1390.66d | 1309.90d | 1261.66d |
| V2T2 | 6.77 | 59.30cd | 143.80a | 207.10a | 589.30d | 895.40d | 915.33f | 851.00f | 823.33f |
| V2T3 | 7.03 | 65.70bc | 182.40a | 274.33a | 644.20cd | 999.40d | 1113.97e | 1056.50e | 1021.33e |
| V1C | 10.43 | 37.70d | 52.00b | 77.10b | 165.50e | 250.33e | 325.60g | 296.60f | 260.33g |
| V2C | 7.47 | 46.33cd | 49.97b | 56.67b | 100.80e | 195.80e | 300.10g | 265.60g | 241.33g |
| S.E | 0.43 | 7.80 | 26.57 | 40.38 | 53.90 | 69.80 | 45.90 | 36.60 | 37.40 |

*Means with the same letter(s) down the column are not significantly different at P= 0.05; Key same as for Table 1; C: control.*

**Table 3:** *The effect of treatment and variety on the mean number of tubers (unit) and weight of tubers (gram) per plant at harvest in the screenhouse.*

| Treatments | Number of tubers | Weight of tubers |
|---|---|---|
| **V1T1** | 2.20b | 52.40c |
| V1T2 | 2.20b | 74.20b |
| V1T3 | 2.80a | 95.00a |
| V2T1 | 2.20b | 73.20b |
| V2T2 | 1.80b | 36.20d |
| V2T3 | 2.00b | 52.80c |
| V1C- | 1.00c | 10.20fg |
| V1C+ | 1.00c | 20.60e |
| V2C- | 1.00c | 4.90g |
| V2C+ | 1.00c | 15.80ef |
| S.E | 0.20 | **2.60** |

*Key: Means with the same letter(s) down the column are not significantly different at P= 0.05; WAP: weeks after planting; TRT 1: effective microorganisms; TRT 2: compost manure; TRT 3: effective microorganisms + compost manure; V1: Boniato; V2: Yellow jersey; S.E: Standard Error; C+: positive control;C–: negative control.*

**Table 4:** *The effect of treatment and variety on the mean number of tubers (unit) and weight of tubers (gram) of Ipomea batatas naturally infested by Meloidogyne incognita on the field per plant at harvest.*

| Treatments | Number of tubers | Weight of tubers (g) |
|---|---|---|
| V1T1 | 27.00b | 3166.70b |
| V1T2 | 30.70ab | 3366.70b |
| V1T3 | 35.70ab | 4766.70a |
| V2T1 | 14.00c | 2716.70b |
| V2T2 | 12.33c | 1366.70b |
| V2T3 | 11.00c | 1450.00b |
| V1C | 41.33a | 683.33cd |
| V2C | 8.70c | 200.00d |
| S.E | 3.50 | 323.20 |

*Means with the same letter(s) down the column are not significantly different at P= 0.05; Key same as for Table 1; C: control.*

**Table 5:** *The effect of treatment on mean vine length (cm) of Ipomea batatas infected with Meloidogyne incognita in the screenhouse.*

| Treatments | WAP | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| TRT 1 | 11.20a | 80.40a | 149.00b | 292.60c | 311.00c | 390.00b | 469.40b | 448.10b | 428.60b |
| TRT 2 | 11.80a | 79.40a | 212.20a | 354.60b | 421.20b | 453.20b | 539.5b | 520.20b | 500.40b |
| TRT 3 | 7.60b | 88.40a | 49.00c | 428.60a | 481.60a | 603.80a | 659.00a | 638.40a | 624.10a |
| -VE CTRL | 4.60b | 13.60b | 19.60c | 25.00e | 33.20e | 41.00d | 39.40d | 39.40d | 26.20d |
| +VE CTRL | 6.20b | 31.00b | 46.80c | 98.20d | 113.80d | 129.60c | 138.40c | 138.40c | 126.40c |
| S.E | 1.2 | 6.10 | 16.60 | 16.50 | 18.9 | 25.00 | 26.90 | 26.40 | 26.40 |

*Key: Means with the same letter(s) down the column are not significantly different at P= 0.05; WAP: weeks after planting; TRT 1: effective microorganisms; TRT 2: compost manure; TRT 3: effective microorganisms + compost manure; S.E: Standard Error; +VE CTRL: positive control; -VE CTRL: negative control.*

**Table 6:** *The effect of treatment on the mean vine length of Ipomea batatas naturally infested by Meloidogyne incognita on the field per plant per week (cm).*

| Treatments | WAP | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| TRT 1 | 8.80 | 73.33b | 143.80ab | 225.00b | 841.00b | 1186.40b | 1565.10b | 1494.07b | 1433.90b |
| TRT 2 | 8.33 | 68.80b | 139.40b | 218.40b | 721.80b | 1233.00b | 1461.10b | 1389.70c | 1358.80b |
| TRT 3 | 8.90 | 87.60a | 194.90a | 289.10a | 998.90a | 1446.00a | 1710.80a | 1639.70a | 1580.80a |
| Control | 8.90 | 42.00c | 50.90c | 66.90c | 133.20c | 223.00c | 312.80c | 281.10d | 250.80c |
| S.E | 0.30 | 3.50 | 14.80 | 16.60 | 40.50 | 46.90 | 34.50 | 26.70 | 24.70 |

*Key: Means with the same letter(s) down the column are not significantly different at P= 0.05; WAP: weeks after planting; TRT 1: effective microorganisms; TRT 2: compost manure; TRT 3: effective microorganisms + compost manure; S.E: Standard Error.*

**Table 7:** *The effect of treatment on the mean number of tubers (unit) and weight of tubers (gram) per plant at harvest in the screenhouse.*

| Treatments | Number of tubers | Weight of tubers (g) |
|---|---|---|
| TRT 1 | 2.2ab | 62.80b |
| TRT 2 | 2.0b | 55.20c |
| TRT 3 | 2.40a | 73.90a |
| -VE CTRL | 1.00c | 7.53e |
| +VE CTRL | 1.00c | 18.20d |
| S.E | 0.10 | 2.10 |

*Means with the same letter(s) down the column are not significantly different at P= 0.05; Key same as for Table 5.*

**Table 8:** *The effect of treatment on the mean number of tubers (unit) and weight of tubers (gram) of Ipomea batatas naturally infested by Meloidogyne incognita on the field per plant at harvest.*

| Treatments | Number of tubers | Weight of tubers (g) |
|---|---|---|
| TRT 1 | 20.50 | 2941.70a |
| TRT 2 | 21.50 | 2366.70a |
| TRT 3 | 23.33 | 3108.33a |
| Control | 25.00 | 441.70b |
| S.E | 2.00 | 246.40 |

*Means with the same letter(s) down the column are not significantly different at P= 0.05; Key same as for Table 6.*

**Table 9:** *The effect of treatment on the nematode population in the screenhouse.*

| Treatments | R.F. | Initial nematode population | Final nematode population | Gall rating |
|---|---|---|---|---|
| TRT 1 | 0.96 | 2400.00 | 2286.50d | 1 |
| TRT 2 | 0.81 | 2400.00 | 1931.00c | 1 |
| TRT 3 | 0.59 | 2400.00 | 1437.00b | 1 |
| -VE CTRL | 1.15 | 2400.00 | 2761.00e | 2 |
| +VE CTRL | 0.00 | 0000.00 | 0000.00a | 0 |
| S.E | | | 62.6 | |

*Means with the same letter(s) down the column are not significantly different at P= 0.05; Key same as for Table 5.*

**Table 10:** *The effect of treatment on nematode population in the field plot.*

| Treatments | Initial nematode population | Final nematode population | R.F. |
|---|---|---|---|
| TRT 1 | 325.00 | 7.80a | 0.02 |
| TRT 2 | 325.00 | 11.20a | 0.04 |
| TRT 3 | 325.00 | 6.80a | 0.02 |
| Control | 325.00 | 19.33b | 0.06 |
| S.E. | | 2.00 | |

*Means with the same letter(s) down the column are not significantly different at P= 0.05; Key same as for Table 6.*

sweet potato plants differed significantly from the controls for all growth and yield parameters (Tables 5-8) and reduced the nematode population in the soil (Tables 9 and 10), thus confirmed as having nematicidal effects. However, both varieties used: Boniato and Yellow jersey sweet potatoes were susceptible to *M. incognita* infection.

The general increase in the growth and yield of Boniato and Jersey sweet potatoes as evidenced in Tables 1-4 may be attributed to the fact that the application of treatments improved the health of the plant and possibly induced resistance against the nematodes and modified the soil to become unfavorable for the pathogens' growth. Izuogu and Usman (2019) reported that compost tea from poultry droppings and cow dung tea gave appreciable yield and managed the population density of *Pratylenchus zeae* on maize; furthermore, improved crop nutrition following treatment application may lead to tolerance of plant-parasitic nematodes and thus an increase in growth and yield of the plants. Efficient translocation is reported to positively affect peanut plant yield (Osman *et al*., 2020).

The significantly better result recorded in Boniato and Jersey plants treated with a combination of effective microorganisms and compost manure as shown in Tables 1-4 may be due to the increase in the population of beneficial microorganisms in the soil which helps control root-knot nematode disease through competitive exclusion as explained by Higa and Wididana (1991). While the organic matter provided in compost manure provides food for microorganisms which further suppresses *M. incognita* and increases recycling of their nutrients for uptake by plants, Hu and Qi (2013) reported that the application of compost manure in combination with effective microorganisms greatly increased wheat straw biomass, grain yield, and the number of free living nematodes, thereby increasing nutrient recycling and decomposition, compared with traditional compost and control treatments. This agrees with Sossou *et al.* (2022), who reported that the combination of EM and compost manure enhanced the tolerance of tomato plants to *M. incognita*.

Stunted plants, chlorosis, decayed roots, and extreme yield reductions in some of the control plants, as shown in Tables 1-8 could be attributed to a higher population of nematodes in these plants, as reported by Moens *et al*. (2009).

Unlike the field experiment, galls observed in the negative control plants of both varieties in the screenhouse experiment ranged from 1-2. This, coupled with a R.F. greater than 1 in all the negative controls in the screenhouse (Table 9) compared to a R.F. less than 1 on the field (Table 10), may indicate proliferation of nematodes and their active penetration due to the absence of EM and compost manure which is further aided by the exclusion of other soil microorganisms in the pot experiment. This is in harmony with the findings of Izuogu *et al*. (2016).

However, the reduction in root-knot index (Table 9), the difference in final nematode population from the initial population and a R.F. less than 1 for *M. incognita* in treated plants (Tables 9 and 10) may be attributed to the direct toxicity of nitrogenous compounds in compost manure as indicated by Kankam (2015) on carrot, and antioxidants present in EM to eggs and/or juveniles; modification of habitat by application of EM to become disease-suppressive soils, thus reducing the root-knot nematodes population density (Higa and Wididana, 1991).

According to the present studies, sweet potato plants treated with a combination of EM and compost manure were more tolerant of *M. incognita* and gave significantly higher yields in spite of the RKN infections. These findings thus demonstrated a combination of EM and compost manure, as potential cost-effective and a novel natural management strategy that can help sweet potato growers and agricultural practitioners seeking sustainable solutions to manage RKN address not only the immediate issue of root-knot nematodes, but also contribute to the overall well-being of the agricultural system.

## Conclusions and Recommendations

Susceptibility of sweet potatoes to *M. incognita* infection reduces yield. The EM technology, along with compost manure, has a nematicidal effect on *Meloidogyne* species in sweet potato plants. If optimized, the infection, proliferation and active penetration of RKN in sweet potato will be greatly inhibited, the growth and yield of the sweet potato plant, enhanced and the prevention of galling on roots is assured.

Besides the diverse environmental applications of EM, such as bioremediation, especially in Asian countries, farmers worldwide should be provided with information on how to produce effective microorganisms and combine them with compost manure in an integrated management practice so as to achieve sustainable agriculture as the climate continues to change and the world population continues to increase.

## Acknowledgements

My gratitude is to Almighty Allah, who has taught man that which he knew not, and with whom all things are possible. I also appreciate Dr. Apalowo Oluropo for his guidance and meaningful contributions to my work.

### Novelty Statement

This research paper highlighted a compelling and innovative approach to tackling the issue of root-knot nematodes management through the utilization of effective microorganisms and compost manure. The peculiarity of its methodology lies in its comprehensive analysis of the interaction between effective microorganisms, compost manure, and root-knot nematodes

## Author's Contribution

**AAA:** Project administration, investigation, data curation, resources, formal analysis, writing-original draft, writing-review and editing.
**NBI:** Conceptualization, supervision, methodology.
**BKS:** Data curation, project administration, investigation.

*Conflict of interest*
The authors have declared no conflict of interest.

## References

Afolami, S.O., Atungwu, J.J., Orisajo, S.B. and Odeyemi, S., 2004. Going beyond gall index in studying and reporting resistance to root knot nematodes. Niger. J. Plant Prot., 21: 25-32.

Atungwu, J.J., Ademola, A.A. and Aiyelaagbe, I.O., 2009. Evaluation of organic materials for inhibition of nematode reproduction in soybean. Afr. Crop Sci. J., 17: 167–171. https://doi.org/10.4314/acsj.v17i4.54292

Barker, K.R., 1985. Nematode extraction and bioassays. In: Baker, K.R., Cater, C.C., and Sasser, J.N. (eds.) An advanced treatise on Meloidogyne. Volume II: Methodology, Graphics, North Carolina State University, United States. pp. 19-35.

Beck, H.E., Zimmermann, N.E., McVicar, T.R., Vergopolan, N., Berg, A. and Wood, E.F., 2018. Present and future Koppen-Geiger climate classification maps at 1-Km resolution. Sci. Data, 5: 180214. https://doi.org/10.1038/sdata.2018.214

Bridge, J. and Page, S.L., 1980. Estimation of root-knot nematode infestation levels on roots using a rating chart. Trop. Pest Manage., 26(3). https://doi.org/10.1080/09670878009414416

Food and Agriculture Organization of the United Nations Statistics Division (FAOSTAT), 2020. Sweet potato production in 2019; World Regions/Production Quantity from pick lists. Available at http://www.feedipedia.org/ (accessed 24 March 2021).

Gautam, C. and Goswami, B.K., 2002. Different combinations of Neem cake and carbofuran against *Meloidogyne incognita* on *vigna radiate*. J. Nematol., 12: 106-110.

Higa, T., 1991. Effective microorganisms: A biotechnology for mankind. In proceedings of the first international conference on kyusei nature farming. U.S. Department of Agriculture, Washington, D.C., USA, pp. 8-14.

Higa, T. and Wididana, G.N., 1991. Changes in the soil microflora induced by effective microorganisms. Proceedings of the first international conference on Kyusei nature farming. U.S. Department of Agriculture, Washington, D.C., USA, pp. 53-162.

Higa, T. and James, P., 1994. Beneficial and effective microorganisms for a sustainable agriculture and environment. International Nature Farming Center, Atami, Japan, pp. 16.

Hu, C. and Qi, Y., 2013. Long-term effective microorganisms' application promotes growth and increase yields and nutrition of wheat in China. Eur. J. Agron., 46: 63–67. https://doi.org/10.1016/j.eja.2012.12.003

Hussey, R.S. and Baker, K.R., 1973. Comparison of methods for collecting inocula of *Meloidogyne* spp., including a new technique. Plant Dis. Rep., 57: 1025-1028.

Izuogu, N.B., Abolusoro, S.A. and Yakub, L.B.,

2016. Nematicidal potential of aqueous extract of *Hyptis suaveolens* in the management of root-knot nematode, *Meloidogyne incognita* of some cowpea cultivars. Croatian J. Food Sci. Technol., 8: 15-19. https://doi.org/10.17508/CJFST.2016.8.1.05

Izuogu, N.B. and Usman, S., 2019. Efficacy of compost tea from animal waste in the management of *Pratylenchus zeae* infecting two maize varieties. J. Agric. Res., 57(3): 167-173.

Kankam, F., 2015. Effect of poultry manure on the growth, yield and root-knot nematode (*Meloidogyne* spp.) infestation of carrot (*Daucus carota* L.). Arch. Phytopathol. Plant Prot., 48(5). https://doi.org/10.1080/03235408.2014.893639

Moens, M., Perry, R. and Starr, J., 2009. Meloidogyne species- a diverse group of novel and important plant parasites. CAB Int: Wallingford, UK pp. 1-17. https://doi.org/10.1079/9781845934927.0001

Onyeka, T.J., Okorocha, E.A. and Anioke, S.C., 2013. An overview of pests and diseases of sweet potato. In: Ukpabio, U.J. and Nwosu, K.L. (ed), yam, cocoyam and sweet potato production and post-harvest management. National Root Crops Research Institute. NRCRI, Nigeria. pp. 265.

Osman, H.A., Ameen, H.H., Mohamed, M. and Elkelany, U.S., 2020. Efficacy of integrated microorganisms in controlling root-knot nematode *Meloidogyne javanica* infecting peanut plants under field conditions. Bull. Natl. Res. Centre, Giza, Egypt, 44: 134. https://doi.org/10.1186/s42269-020-00366-0

Overstreet, C., 2009. Nematodes. In: Loebenstein, G. and Thottappily, G. (ed). The sweet potato. Springer Sci, Germany. pp. 131-155.

Precision Report, 2023. Effective microorganisms (EM) market. Available at https://www.marketwatch.com/press-release/effective-microorganisms-em-market-2030-2023-05-12. (accessed 12 May 2023).

Sossou, B.K., Izuogu, N.B., Anifowose, A.O. and Ahamefule, H.E., 2022. Controlling root-knot nematode *Meloidogyne incognita* in tomatoes using modified effective microorganisms-fermented plant extract and compost manure. Int. J. Recycl. Organic Waste Agric., 11: 427-436.

SPSS Predictive Analytics, 2017. What's new in SPSS Statistics 25 and Subscription. Available at http://www.developer.ibm.com/ (accessed 18 July 2017).

TeraGanix, Inc., 2015. Higa, T. EM: A holistic technology for humankind. Available at http://www.pssurvival.com/ (accessed 27 November 2015).

Thaler, M. and Safferstein, D., 2014. A curious harvest: The practical art of cooking everything. Quayside Publishing Group, United States. pp. 129.

Ukpabio, U.J., Ekeledo, E.N. and Ezigbo, V.U., 2012. Potential use of roots of orange fleshed sweet potato genotypes in the production of B-carotene rich chips in Nigeria. Afr. J. Food Sci., 6: 2. https://doi.org/10.5897/AJFS11.186

Velmurugan, P., 2017. Extraction of natural colorant from purple sweet potato and dyeing of fabrics with silver nanoparticles for augmented antibacterial activity against skin pathogens. J. Photochem. Photobiol., 173: 571-579. Available at http://www.ncbi.nlm.nih.gov, https://doi.org/10.1016/j.jphotobiol.2017.07.001