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Management of *Meloidogyne incognita* Infecting Eggplant Using Moringa Extracts, Vermicompost, and Two Commercial Bio-products

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ABSTRACT

Two greenhouse pot experiments were conducted to assess the effectiveness of dried leaf powder and extractives (ethanolic, and aqueous extracts) of Moringa (*Moringa oleifera*) or organic fertilizer (vermicompost) and two commercial products namely BioNematon (*Purpureocillium lilacinum*) and Abamectin, Gold (*Streptomyces avermitilis*) on eggplant growth parameters and *Meloidogyne incognita* infection. In both experiments observed data revealed that combined applications showed better performance than did single ones. Eggplant growth parameters in terms of fresh shoot and root lengths, and shoot and root weights were remarkably improved with single application of Abamectin or BioNematon followed by plant extracts or vermicompost resulting in a significant (P<0.05) suppression in nematode population in soil and root as well as the number of galls and egg masses. However, the potential of bioagent was increased with the addition of Moringa leaf powder and significantly (P<0.05) enhanced eggplant growth and suppressed nematode population, root galling and female fecundity even no significant differences were recorded compared to Oxamyl. Vermicompost derived from municipal wastes showed a low C/N ratio (1:14) with an excess of nitrogen that exhibited nematicidal activity against *M.incognita*. The addition of vermicompost with such bio-agents showed a synergistic effect upon nematode population, root galling and number of females. Significant differences whether in plant growth or nematode reproduction were not detected compared to Oxamyl. Thus the current study revealed the potential of leaf powder and extractives of Moringa, vermicompost, *P.lilacinum* and *S.avermitilis* as safe alternatives to control *M.incognita* infecting eggplant through an integrated management program and bring sustainability to agriculture.

Keywords: *Streptomyces avermitilis, Purpureocillium lilacinum,* Vermicompost, *Meloidogyne incognita*.

INTRODUCTION

Eggplant is a major fruit vegetable crop with global production in 2018 exceeding 52 million tonnes (FAOSTAT, 2019).Root-knot nematodes, *Meloidogyne* spp. are considered one of the most important pathogens causing substantial damage to eggplants grown in tropical and subtropical regions (Hussain et al., 2015). The use of nematicides is the most desirable method for the management of root-knot nematodes. However, their adverse effects on the environment, ground water, soil texture, human, plant and animal health (Meyer, 2003), led scientists to search for ecofriendly alternatives strategies. Among these strategies plant extractives that have been shown nematicidal properties against root-knot nematodes, *Meloidogyne* spp. under greenhouse and field conditions and their potential for use in nematode control programs has been suggested (Ismail, 2013; Sowley et al., 2018 ; Mainoo and Banful, 2019; El Deriny et al., 2020).

Another possible alternative is the use of vermicompost which is particularly interesting because of its low cost and positive effect on plant growth, physical, chemical, and biological properties of the soils (Arancon et al., 2005; Gabour et al., 2015). Vermicomposting is a mesophilic process utilizing earthworms to turn the organic waste material into high-quality compost known as vermicompost that consists mainly of worm cast in addition to decayed organic matter (Devi and Prakash 2015; Mohamed et al., 2019). Vermicompost has been found to have beneficial effects when used as soil amendments in field studies (Pathma and Sakthivel, 2012; Mohamed et al., 2019). In particular, the suppressive effect of vermicompost on plant-parasitic nematodes was documented (Singh and Prasad, 2014; Gabour et al., 2015; Mohamed et al., 2019).

Bacteria and fungi are the most important biocontrol agents that have been studied. For instance, Abamectin a natural fermentation product of the bacterium *Streptomyces avermitilis* was reported to have nematicidal activity against different genera of plant nematodes (Youssef and Lashein, 2015; Sasanelli et al., 2019)**.** The common soil fungus, *Purpureocillium lilacinum* (Formerly *Paecilomyces lilacinus*) is well known as a facultative egg pathogen of sedentary nematodes. Its nematicidal activity against different plant nematodes was documented (Pura and Matiyar, 2016; Ganaie, 2018; Metwally et al. 2019).

The objective of this research was to explore the impact of Moringa plant extracts, granular vermicompost integrated with two commercial biocontrol agents on *M. incognita* infection and eggplant growth response.

MATERIALS AND METHODS

1.Moringa leaf extracts

Moringa leaf powder

Fresh leaves of *Moringa* (*Moringa oleifera* Lam, Fam: Moringaceae) were collected, washed by distilled water and air dried under room temperature (25-27 ºC). Leaves were then crushed and screened by a specific mesh sieve to get the moringa powder. Moringa leaf powder samples were then stored in a sterilized bag.

Ethanolic leaf extract

Moringa powder (0.4 g) was soaked in 100 ml of the selected solvent (ethanol 95 %) for two hours. Solutions were then centrifuged at 2000 rpm for ten minutes and filtered through Whatman No.1 filter paper.

Aqueous leaf extract

Twenty-five grams of thoroughly washed and chopped fresh leaves of moringa were ground separately in an electric blender in 100 ml of distilled water. Solutions were then centrifuged at 5000 rpm for five minutes and filtered through Whatman No. 1 filter paper.

2.Vermicompost

An organic fertilizer which was brought from Olive Research Department, Horticultural Research Institute, Giza, Egypt.

3.Commercial bio-products

1.BioNematon® 1.15% WP, a commercial product of *Purpureocillium lilacinum* which contains 1x 10^8cfu/g of fungus. A solution of 2.5g/100ml distilled water was prepared.

2.Gold (Abamectin)® 1.8 % EC, a commercial product of *Streptomyces avermitilis* which contains 1x 10^8cfu/g of bacterium. Abamectin was added at a concentration of 400ppm (0.4 ml Abamectin/ 1000ml distilled water).

4. Nematicide
Oxamyl: (Vydate 10% G.) Methyle – N – N – dimethyl – (N (methyle) carbomycocyl) –1- hioxamidate,.

Experimental Design

<u>A.Impact of Moringa leaf extractives and two bio-products on *Meloidogyne incognita* infecting eggplant</u>

Seedlings of eggplant cv. Black king (30 days old) were separately transplanted in plastic pots (13 cm-diam) filled with 850 g steam sterilized clay loamy soil (Coarse sand 1.90; Fine sand 26.5; Silt 32.6 ; Clay 36.5). Five days after transplanting, seedlings were inoculated with approximately 1500 eggs of *M. incognita*. Five days later Moringa extracts (Aqueous and Ethanolic extracts) as well as dried leaf powder were introduced to soil pots. Aqueous and Ethanolic extracts of Moringa were applied as a soil drench at the concentration of 5ml/pot. Moringa leaf powder was incorporated into the soil at the rate of 5g/pot. Simultaneously, the commercial biocide, Gold 1.8 % EC (Abamectin) or BioNematon were applied singly and in combination. All pots were slightly irrigated following treatments. The conventional nematicide, Oxamyl was applied at the recommended rate (0.3g/pot) two days after nematode inoculation for comparison. Pots free of nematode inoculum were served as a negative control, however, those received nematode inoculum served as the positive control. Each treatment was replicated four times. All plastic pots were irrigated with water as needed and arranged in a randomized-complete block design (RCBD) and agronomically treated the same under green house conditions.

Treatments were as follows: 1-Moringa leaf powder (MP); 2- Ethanolic extract of Moringa (EM); 3-Aqueous extract of Moringa(AM); 4-Gold (Abamectin, *S.avermitilis*) (G); 5-BioNematon; 6-Moringa leaf powder + Gold(MP+G); 7-Ethanolic extract of Moringa + Gold (EM+G) ;8-Aqueous extract of Moringa + Gold (AM+G); 9-Moringa leaf powder+ BioNematon(MP+BN); 10-Ethanolic extract of

Moringa +BioNematon (EM+BN); 11-Aqueous extract of Moringa+ BioNematon (AM+BN); 12-Oxamyl (O); 13-Plant free of Nematode and 14-Nematode only.

B.Impact of vermicompost and two bio-products on *Meloidogyne incognita* infecting eggplant

The same protocol as outlined before was repeated using vermicompost. Treatments were as follows: 1-Vermicompost (VC); 2-Gold (Abamectin) (G) 3-BioNematon(BN); 4- Vermicompost +BioNematon (VC+BN); 5– Vermicompost + Gold (VC+G); 6-Oxamyl (O); 7- Plant free of Nematode and 8- Nematode only.

For both experiments, fifty five days after nematode inoculation, plants were harvested. Data on growth performance (length and fresh weight of shoots, root as well as shoot dry weight) were recorded. Second stage juveniles of *M. incognita* were extracted from soil using sieving and modified Baermann-technique according to Goodey (1957) and counted. Roots were stained in acid fuchsin lactic acid (Byrd et al., 1983), washed in tap water and placed in pure cold glycerin. Numbers of galls, egg masses, females, and development stages were determined with the aid of a stereo-microscope and recorded. The root-knot nematode reproduction (Rf) was calculated. Root gall (RGI) index was determined according to the scale given by Taylor and Sasser (1978).

Biochemical Analysis of Moringa extractives

The aqueous and ethanolic extracts of *M.oleifera* were separately screened for the presence of bioactive constituents using standard phytochemical techniques as described by Arefin et al. (2015) Ashtalakshmi and Prabakaran (2015) and Usharani et al. (2016).

Flavonoids

The presence of flavonoids in Moringa extracts was detected according to the method of Arefin et al. (2015). One ml Moringa extract of each investigated sample was treated with few drops of 10% $(CH_3COO)_2Pb$. The presence of yellow precipitate affirms the presence of flavonoids.

Saponins

The presence of saponins was detected according to the method of Arefin et al. (2015). One ml Moringa extract of each investigated sample was added to five ml of distilled water and well shaked. The appearance of foam measuring about one cm^3 indicates the presence of saponins.

Tannins

The presence of tannins was examined by the method detailed by Usharani et al. (2016). One ml of Moringa extract of each investigated sample was added to five ml of distilled water and placed for boiling in a hot water bath for 5 min. Then the samples were cooled down at room temperature and few drops of 5% $FeCL_3$ solution were added. The appearance of brownish green colour confirms the occurrence of tannins.

Phenols

The presence of phenols was examined by the method detailed by Usharani et al. (2016). Few drops of 5% $FeCL_3$ solution were added to two ml Moringa extract of each investigated sample. Presence of dark green colour emphasizes the existence of phenols.

Glycosides

The presence of glycosides was detected using Molish's reagent according to Ashtalakshmi and Prabakaran (2015). Two ml Moringa extract of each investigated sample were added to one ml of Molish's reagent followed by one ml of Conc. H_2SO_4 along the wall of the test tube. Formation of purple ring at the intersection of two liquids indicates the presence of glycosides.

Data analysis

All the obtained results were subjected to analysis of variance (ANOVA) followed by Duncan multiple range tests to compare means (Duncan, 1955). The least significant differences (LSD) at the 5% level of probability were determined using a computer program CoStat Version.

RESULTS AND DISCUSSION

Integrated control is a sustainable approach for to the management of plant-parasitic nematodes. The root-knot nematode, *M. incognita* caused a significant decrement in plant growth parameters with a reduction percentage in plant length and total plant fresh weight reached 21.6 and 39.6 %, respectively.(Table 1).Individual application of BioNematon (commercial product of egg parasitic fungi *Purpureocillium lilacinum*) and Gold (commercial product of the soil bacterium *Streptomyces avermitilis* surpassed Moringa plant extracts and showed the best augmentation in plant length, total plant fresh weight and shoot dry weight (Table1) and significantly suppressed nematode population, number of females, galls and egg masses compared to untreated plants (Table 2). These results support the findings of Oclarit and Cumagun ,2009; Metwally et al., 2019; Sasanelli et al., 2019). BioNematon suppressed nematode population through colonization on roots as well as on egg mass and female body, thereby destroying females, and eggs of *Meloidogyne* spp. (Cardona and Leguizamon, 1997; Azam et al., 2013). The enzymes i.e. protease and chitinase produced by *P. lilacinum* (Khan et al., 2006) are indeed effective in hyphal penetration through the cuticle of juveniles and females of *M. javanica*. Moreover, *Streptomyces avermitilis* can produce secondary metabolites that showed nematicidal activity against root-knot nematodes in a large number of crops under different conditions (Khalil, 2013; Metwally et al., 2019).

Moringa oleifera (Lam) leaves are rich in important minerals as Calcium, Manganese, Potassium, Iron, Zink, Phosphorous,Copper Magnesium, Sulphur and Sodium which lead to an increase in plant growth, yield (Olajide et al., 2018). In the present investigation Moringa plant extracts showed no phytotoxicity to eggplant infected with *M.incognita*. Moringa powder leaf was superior in enhancing plant growth attributes i.e. shoot length and shoot fresh weight followed by aqueous leaf extract then ethanolic extract (Table 1). This confirmed the report by Sowley et al. (2013) that application rates of Moringa leaf powder increased sweet pepper plant growth and yield and decreased nematode population indicating their potential in the management of root-knot nematodes. Powdered leaves of moringa may change the physical structure and soil fertility resulting in increased tolerance of the plants to nematode attack (Mahmood and Saxena, 1992). The presence of cytokinin group in the ethanolic extract of Moringa leaves influenced height in sweet pepper plants (Makkar and Becker,1996).

Table1: Combined effect of Moringa extracts and Gold (Abamectin) or BioNematon on growth of eggplant infected with *Meloidogyne incognita***.**

	Plant Growth Response							
Treatments	Shoot Length (cm)	Plant Length (cm)	Inc. %	Shoot Fresh weight (g)	Plant Fresh weight (g)	Inc. %	Shoot Dry weight (g)	Inc.%
MP	24.5a-c	38.8	9.9	5.8a-e	8.3	23.9	1.4a-c	27.3
EM	23.8b-d	35.8	1.4	4.8c-e	7.3	9.0	1.4a-c	27.3
AM	23.0cd	36.0	2.0	5.4a-e	8.0	19.4	1.3a-c	18.2
G	23.7b-d	39.4	11.6	6.8ab	10.3	53.7	1.4a-c	27.3
BN	26.0ab	42.3	19.8	6.6ab	10.6	58.2	1.4a-c	27.3
MP+G	24.7a-c	43.0	21.8	5.4a-e	10.9	62.7	1.2bc	9.1
EM+G	26.0ab	42.2	19.5	5.8a-e	10.6	58.2	1.2bc	9.1
AM+G	25.3a-c	41.6	17.8	6.6 ab	11.0	64.2	1.3a-c	18.2
MP+ BN	24.3a-c	45.0	27.5	5.7a-e	11.3	68.7	1.3a-c	18.2
EM+BN	25.0a-c	41.0	16.1	5.9a-e	10.8	61.2	1.3a-c	18.2
AM+BN	25.3a-c	41.3	17.0	5.5a-e	10.6	58.2	1.7a	54.5
O	22.3cd	36.8	4.2	5.2b-e	8.4	25.4	1.3a-c	18.2
Healthy Plants	27.7a	45.0	27.5	7.5a	11.1	65.7	1.5ab	36.4
Nematode only (N)	20.5d	35.3	---	4.2de	6.7	---	1.1c	---

Each value is the mean of four replicates. MP= Moringa leaf powder; EM= Ethanol extract of Moringa; AM= Aqueous extract of Moringa G= Gold (Abamectin *Streptomyces avermitilis*); BN=BioNematon *Purpureocillium lilacinum*; O=.Oxamyl; N= 1500 eggs of *M. incognita*.
Means in each column followed by the same letter (s) did not differ at $P< 0.05$ according to Duncan multiple- range test.

Hence, in dual applications a synergistic impact on eggplant growth in terms of fresh shoot and root lengths, total plant fresh weight was induced with various degrees as compared with a single application. A pronounced improvement in shoot length was recorded with the mixture of powder extract of Moringa (MP) and Abamectin (G) or Moringa (MP) with BioNematon with percentages of increase in plant length amounted to 21.8 & 27.5%, respectively. Similar trend was noticed with shoot fresh weight with percentages of increase in total plant fresh weight amounted to 62.7& 68.7%, respectively.

Table 2: Combined effect of Moringa extracts and Gold (Abamectin) or BioNematon on *Meloidogyne incognita* population and reproduction on eggplant.

Treatments	Nematode population in			Total nematode population	Red %	Rf*	No.galls	RGI**
	Root		Soil					
	D.S	Females						
MP	3.8b	9.5b	1364.8b	1378.1	53.0	0.9	12.8b	2.5
EM	2.5b	6.8b	958.8b-d	968.1	67.0	0.6	8.5b	2.3
AM	2.8b	6.3b	1231.0bc	1240.1	57.7	0.8	8.0b	2.3
G	2.3b	5.3b	820.0c-e	827.6	71.8	0.5	7.3b	2.3
BN	2.3b	6.7b	718.3c-e	727.3	75.2	0.5	8.0b	2.3
MP+G	3.3b	6.0b	743.3c-e	752.6	74.4	0.5	8.3b	2.3
EM+G	2.3b	3.7b	430.0d-f	436.0	85.1	0.3	5.3b	2.0
AM+G	2.3b	4.3b	712.3de	718.9	75.5	0.4	4.7b	1.8
MP+ BN	2.0b	4.7b	695.0de	701.7	76.1	0.5	6.7b	2.3
EM+BN	0.8b	3.0b	478.3d-f	482.1	83.6	0.3	3.3b	2.0
AM+BN	0.3b	3.7b	680.0de	684.0	76.7	0.5	5.3b	2.0
O	2.3b	1.3b	348.8ef	352.4	88.0	0.2	1.5b	1.0
Nematode only (N)	18.0a	40.0a	2875.0a	2933.0	-----	2.0	55.5a	2.8

Each value is the mean of four replicates. MP= Moringa leaf powder EM= Ethanol extract of Moringa AM= Aqueous extract of Moringa ; G= Gold (Abamectin) *Streptomyces avermitilis* BN=BioNematon *Purpureocillium lilacinum* ; O=.Oxamyl (10%G); N=1500 eggs of *M. incognita*. *Rf= Reproduction factor = Final population(Pf)/Initial population(Pi).

**Root gall index (RGI) was determined according to the scale given by Taylor& Sasser (1978) as follows0= no galls; 1= 1-2; 2= 3-10; 3= 11-30; 4=31-100 and 5= more than 100 galls.

Means in each column followed by the same letter (s) did not differ at P< 0.05 according to Duncan multiple- range test.

Soil nematode population, root galling and the number of females of *M.incognita* were significantly suppressed ($p < 0.05$) by all plant extracts of Moringa compared to untreated plants (Table 2). However, ethanolic leaf extract of moringa being the most effective in reducing soil nematode population, number of females and root galling followed by aqueous extract as well as moringa leaf powder even no significant differences in nematode parameters among plant extracts were indicated. According to Claudius-Cole et al. (2010) and Youssef et al. (2014) reports, *M. oleifera* leaves contain nematicidal properties that inhibit nematode egg hatching and juvenile survival which may have resulted in increased plant growth parameters in treated plants. The nematicidal effect of the Moringa leaf powder could be attributed to its high content of certain oxygenated compounds with lipophilic properties that enable them to dissolve the cytoplasmic membrane of nematode cells and their functional groups interfering with the enzyme protein structure (Konstantopoulou et al.,1994). Apparently, our data suggest that the combination of Moringa extracts with either bioproduct BioNematon (*P.lilacinum*) or Gold *S. avermitilis* gave better results than did a single one (Table 1). Moreover, the present findings demonstrate that the combination of Moringa extracts with BioNematon or Gold plays a synergistic effect on minimizing *M.incognita* on eggplant (Table 2).

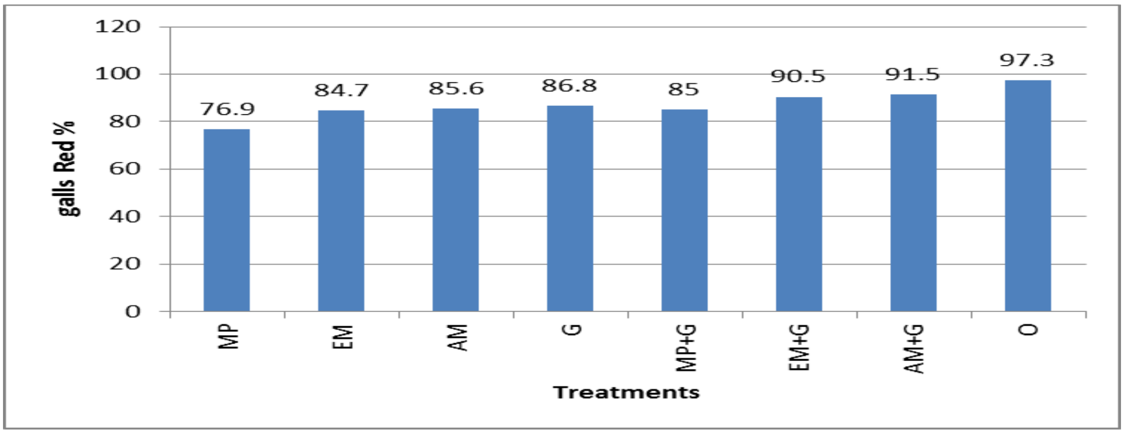

Fig.1: Reduction percentage in the number of galls of *Meloidogyne incognita* infecting eggplant as influenced by the addition of Moringa extracts and Abamectin.

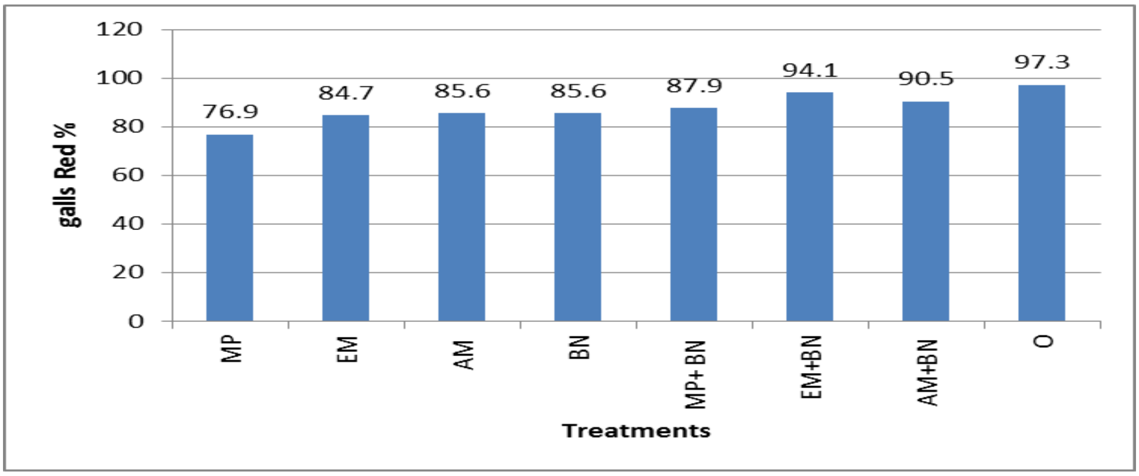

Fig.2: Reduction percentage in the number of galls of *Meloidogyne incognita* infecting eggplant as influenced by the addition of Moringa leaf extract and BioNematon.

MP= Moringa leaf powder EM=Ethanolic extract of Moringa AM= Aqueous extract of Moringa BN= BioNematon O=.Oxamyl

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Co-application of such bioagents significantly (P>0.05) suppressed *M. incognita* population, root galling, number of females and egg masses and reproduction factor. The highest reduction in total nematode population and reproduction factor was performed with the combination of ethanolic extract of Moringa (EM) and Gold or BioNematon. Next to Oxamyl (97.3%) root galling was significantly suppressed with EM +BioNematon (94.1%) (Fig.1) and AM+Gold (91.5%) (Fig.2.). However, significant difference in root galling in most treatments was not detected. Females fecundity in terms of the number of egg masses and the number of eggs/single egg mass was significantly ($P<0.05$) reduced by all treatments compared to untreated plants. Previous studies revealed that combination of biocontrol agents provides effective control of root-knot nematodes in pot and field experiments (Ashraf and Khan,2008; Murslain et al., 2013 & 2014; Udo et al., 2014; El Deriny, 2016). The invasion and development of *M. javanica* on eggplant were greatly affected with standard concentration of combined application of *M.oleifera* and *Trichoderma harzianum* (Murslain et al., 2013). Meanwhile, Udo et al. (2014) reported that double inoculation with *P. lilacinus* in combination with *Lantana camara* leaf extract changed the susceptibility of the tomato cultivar and was the most effective treatment in gall and egg mass inhibition, growth enhancement and dry matter accumulation.

Chemical analysis of Moringa plant extracts (Ethanolic and Aqueous leaf extracts) indicated the presence of the active ingredients i.e. flavonoids, saponins, glycosides, phenols and tannins (Table 3) that exerted nematicidal activities (Ntalli et al., 2009; Ohri and Pannu, 2010; Nguyen et al., 2013). Extraction with distilled water showed better performance in such constituents than with ethanol. This finding is on a par with results of other researchers (Mittal et al., 2007; Isitua et al., 2015).

Table 3: Phytochemical constituents in leaf extracts of *Moringa oleifera*.

Solvents	Flavonoids	Saponins	Glycosides	Tannins	Phenols
Ethanol	+ +	+	+ + +	+	+
Distilled Water	+ +	+ + +	+ + +	+ +	+ +

*Key: +++, Highly present; ++, Moderately present; +, Slightly present; -Not present

Moringa extracts showed greater performance in glycosides. Saponins are a large group of glycosidic secondary metabolites produced by many plant species and were more detected in aqueous leaf extracts of Moringa than stem or root extracts (Khairy, 2016). Herein, saponins were highly present in aqueous leaf extract of *M.oleifera*. Saponins have been found effective in vitro against *Xiphinema index*, *M.incognita* and *Globodera rostochiensis* (D'Addabbo et al., 2010). Whereas, tannins, phenols and flavonoids were moderately present in aqueous leaf extract (Table 3). Phenolic compounds may serve as defense compounds against plant pathogens and number of them have shown strong nematicidal activity (Ohri and Pannu, 2010).

The application of vermicompost as organic fertilizer rich in NPK and micronutrients has been reported to significantly suppress plant-parasitic nematodes (Ramakrishnan and Mahadevaswamy, 2011; Hemmati and Saeedizadeh, 2019; Awad-Allah and Khalil, 2019) and as an excellent promoter and protector for crop plants (Chauhan and Singh, 2015). In the present study, vermicompost derived from municipal wastes enhanced plant growth attributes in terms of shoot length (18.5%), total plant fresh weight (32.8%) (Table 4) and significantly reduced ($p \leq 0.05$) nematode population (64.9%) and root galling (82.5%) (Fig.3) compared to untreated

Table 4: Combined effect of vermicompost and Gold (Abamectin) or BioNematon on the growth of eggplant infected with *Meloidogyne incognita* .

Treatments	Plant Growth Response							
	Shoot Length (cm)	Plant Length (cm)	Inc.%	Shoot Fresh weight (g)	Plant Fresh weight (g)	Inc.%	Shoot. Dry.wt (g)	Inc.%
VC	24.3a-c	38.3	8.5	6.4ab	8.9	32.8	1.3a-c	18.2
G	23.7b-d	39.4	11.6	6.1a-c	9.6	43.3	1.4ab	27.3
BN	26.0ab	42.3	19.8	6.6ab	10.6	58.2	1.4ab	27.3
VC+ G	23.3b-d	37.8	7.1	6.7a	10.7	59.7	1.3a-c	18.2
VC+ BN	22.7b-d	39.0	10.5	5.7a-c	9.8	46.3	1.2bc	9.1
O	22.3cd	36.8	4.2	3.8c	8.4	25.4	1.3a-c	18.2
Healthy Plants	27.7a	45.0	27.5	7.5a	11.1	65.7	1.5a	36.4
Nematode only(N)	20.5d	35.3	---	4.2bc	6.7	---	1.1c	--

Each value is the mean of four replicates. VC=Vermicompost G= Gold (Abamectin,*Streptomyces avermitilis*); BN= BioNematon,*Purpureocillium lilacinum* ;O=.Oxamyl . N=1500 eggs of *M. incognita* Means in each column followed by the same letter (s) did not differ at P< 0.05 according to Duncan's multiple- range test.

Table 5: Combined effect of vermicompost and Gold (Abamectin) or BioNematon on *Meloidogyne incognita* population and reproduction on eggplant.

Treatments	Nematode population in			Total nematode population	Red%	Rf*	No. of galls	RGI**
	Root		Soil					
	D.S	Females						
VC	2.7b	7.7b	1018.4b	1028.8	64.9	0.7	9.7b	2.3
G	2.3b	5.3b	820.0bc	827.6	71.8	0.6	7.3b	2.3
BN	2.3b	6.7b	718.3bc	727.3	75.2	0.5	8.0b	2.3
VC+ G	2.6b	5.3b	685.0bc	692.9	76.3	0.5	7.7b	2.3
VC+ BN	3.7b	5.3b	591.7b-d	600.7	79.5	0.4	8.0b	2.3
O	2.3b	1.3b	348.8cd	352.4	88.0	0.2	1.5b	1.0
Nematode only(N)	18.0a	40.0a	2875.0a	2933.0	---	2.0	55.5a	2.8

Each value is the mean of four replicates. VC=Vermicompost ; G=Gold (Abamectin, *Streptomyces avermitilis*); BN= BioNematon *Purpureocillium lilacinum*; O=.Oxamyl N=1500 eggs of *M. incognita*.

*Rf= Reproduction factor = Final population(Pf)/Initial population(Pi); **Root gall index (RGI) was determined according to the scale given by Taylor& Sasser (1978) as follows : 0= no galls; 1= 1-2; 2= 3-10; 3= 11-30; 4=31-100 and 5= more than 100 galls). Means in each column followed by the same letter (s) did not differ at P< 0.05 according to Duncan's multiple- range test

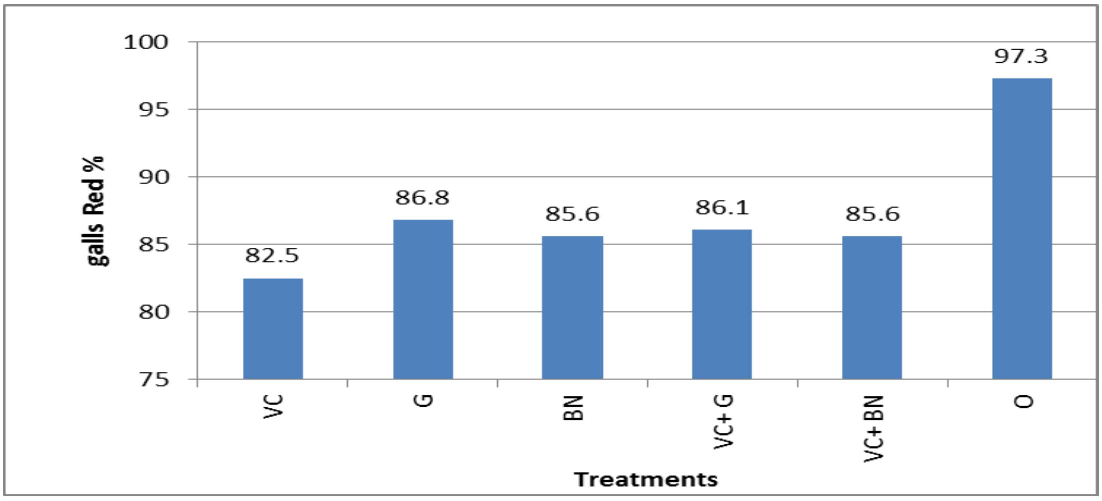

Fig3: Reduction percentage in the number of galls of *Meloidogyne incognita* infecting eggplant as influenced by the addition of vermicompost , BioNematon and Abamectin.

VC=Vermicompost , G= Gold (Abamectin) , BN= BioNematon, , O=.Oxamyl

plants (Table 5). Both Abamectin and BioNematon surpassed vermicompost in promoting total plant fresh weight, however a synergistic effect on such criterion was recorded with the combinations of vermicompost and Abamectin (Table 4). The suppression of *M. incognita* population and reproduction on eggplant by *P.lilacinum* or Abamectin *S.avermitilis* was increased with the addition of vermicompost even no significant differences were noticed (Table 5).Females fecundity in terms of the number of egg masses and the number of eggs/single egg mass was significantly ($P<0.05$) reduced by all treatments. According to Arya (2016) reports combined inoculations of *T. harzianum* and vermicompost proved effective in reducing infection of *M. incognita* and increasing the germination percentage of tomato. Many mechanisms can be involved in the suppression of vermicompost such as decomposition into the soil and ammonia production stimulation of soil microbial biomass and release of biocidal substances that have nematicidal activity (Oka & Yermiyahu, 2002). Nematodes can also be killed by toxic substances such as hydrogen sulfide, ammonia, and nitrites released during vermicompost degradation in the soil (Rodriguez-Kábana, 1986).

Chemical analysis of the studied vermicompost revealed an excess of ammonium (67 ppm), nitrate (179 ppm) and low C/N ratio 1:14.(Mohamed et al., 2019). Higher availability of nitrogen enhances the nematicidal activity of manures against plant-parasitic nematodes (Mian and Rodriguez-Kábana 1982). So, materials with lower C: N ratios are more nematicidal than those with higher ratios (Ismail et al. 2006; Renčo et al. 2011).

In conclusion, our results suggested that the addition of Moringa extracts or vermicompost, with BioNematon or Abamectin provided significant effective control against *M. incognita* infecting eggplant. However, no significant differences were demonstrated compared to Oxamyl. Because of the high price of nematicides and synthetic fertilizers, the uses of Moringa extracts or vermicompost as organic fertilizers combined with biopesticides are thus promising for the control of root-knot nematodes in sustainable agricultural systems and offer cheap and safe nematicidal alternatives. However, further studies are required using Moringa extractives and vermicompost integrated with one or two bioagents with different mechanisms for the management of root-knot nematodes under greenhouse and field conditions.

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الملخص العربى

مكافحة نيماتودا تعقد الجذور التى تصيب نبات الباذنجان باستخدام مستخلصات المورينجا، فيرميكمبوست واثنان من المركبات التجارية الحيوية

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تم إجراء تجربتين لتقييم فعالية المسحوق الورقى الجاف ومستخلصات نبات المورينجا (مستخلص الإيثانول ، المستخلص المائى) او السماد العضوي (vermicompost) مع اثنان من المنتجات التجارية الحيوية BioNematon (*Purpureocillium lilacinum*) و Gold1.8% Abamectin (*Streptomyces avermitilis*) على نمو نباتات الباذنجان وتعداد النيماتودا *Meloidogyne incognita* تحت ظروف الصوبة . في كلتا التجربتين اظهرت النتائج كفاءة استخدام المعاملات المشتركة عن المعاملات الفردية. تحسن نمو نباتات الباذنجان من حيث اطوال وأوزان المجموع الخضري والجذرى بشكل ملحوظ. .من خلال المعاملات الفرديه لكل من Abamectin و BioNematon يلي ذلك المعاملة بالمستخلصات النباتية أو vermicompost ما ادى الى الخفض المعنوى لتعداد النيماتودا في التربة والجذور بالإضافة إلى اعداد العقد الجذرية وكتل البيض. بينما فى حالة المعاملات المشتركة نجد ان اضافة مسحوق اوراق المورينجا مع المنتج الحيوي كان الأكثر فعاليه وأظهرت تاثيرا معنويا بشكل ملحوظ (P<0.05) في تحسن نمو نباتات الباذنجان وخفض تعداد النيماتودا في التربة والجذور وكذلك اعداد العقد وكتل البيض مع عدم تسجيل فروق معنوية مقارنة بالأوكساميل.

أظهرت المعامله Vermicompost نسبة C/N منخفضة (1:14) مع زيادة النيتروجين التي تسببت في نشاط ابادى ل *M.incognita*. كما أظهرت إضافتها مشتركه مع المنتجات الحيوية المختبرة Abamectin و BioNematon تأثيرًا معنويا على تعداد النيماتودا ، وعدد العقد وكتل البيض. ولم تسجل اي فروق معنويه سواء في نمو النبات أو تعداد النيماتودا مقارنة بالأوكساميل. وبالتالي إمكانية استخدام مستخلصات نبات المورينجا المختبره، Vermicompost، والمنتجان التجاريان *P.lilacinum* و *S.avermitilis* كبدائل آمنة لمكافحة *M.incognita* التي تصيب نباتات الباذنجان ضمن برنامج مكافحه متكاملة وتحقيق التنمية المستدامة.