J. Plant Prot. and Path., Mansoura Univ., Vol.9 (7): 405– 410, 2018

Impact of Plant Oils, Biocontrol Agents and Oxamyl on Galling and Reproduction of *Meloidogyne incognita* Infecting Pepper Cultivars

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ABSTRACT

A greenhouse experiment was carried out to evaluate the nematicidal activity of two biopesticides (Nema k & Nema clean), two plant oils (*Inula viscosa* & *Azadirachata indica*) and two entomopathogenic nematodes, (EPNs) i.e. *Steinernema feltiae* and *Heterorhabditis bacteriophora*) compared to chemical nematicide, oxamyl on root-knot nematode, *Meloidogyne incognita* infecting three cultivars of pepper (*Capsicum annuum* L.). Biopesticides were applied at the rate of 0.4 ml /plant whereas, the plant oils were tested at the concentration of 400 µL\plant. EPNs were accomplished simultaneously with inoculation of *M. incognita* as a liquid suspension of alive infective juveniles (IJs) at rate of 5000 IJs/plant in sandy soil. Oxamyl at recommended rate of 0.2 ml/plant. Control treatments received only water and *M. incognita* at rate of 1000 IJs/plant. Two months after application, galling (as indicated by number of galls/plant) and reproduction (as indicated by number of egg masses /plant) as well as damage (as indicated by fresh and dry weight of areal parts) were assessed. Data showed that, oxamyl treatment surpassed all other treatments in minifying galling and reproduction of *M. incognita* in sandy soil. From all tested materials, oxamyl, biopesticides and EPNs were the most effective in suppressing root galling and number of egg masses of *M. incognita* infecting pepper cultivars. On contrarily, plant oils were the least effective ones. Maximum percentages of reduction were recorded on cultivar 1515 when plants were treated with oxamyl (92.17&79.47%) followed by *S. feltiae* (90.21& 70.19%) and biopesticide, Nema clean (89.34 & 68.86%). On the other hand, statistically oxamyl was the first tested material in declining number of infective juveniles of *M. incognita* on three peppers cultivars. The curative application with oxamyl and Nema clean (*Serratia marcescens*) achieved the highest percentage increase in fresh (47.11 & 41.33) and dry (16.59 & 16.67) shoot weight, respectively. Next to oxamyl, entomopathogenic nematodes (*S. feltiae*) showed better performance in diminishing number of galls and egg masses of *M. incognita* infecting pepper cv. Lama than did on cv. Rima. However, the maximum percentages of increase in fresh and dry shoot weights of pepper were recorded on cv. Lama in pots receiving oxamyl (11.48 & 32.70%) and Nema clean (9.47& 27.50%).

Keywords: Control, *Meloidogyne incognita*, oxamyl, *Heterorhabditis bacteriophora* , *Steinernema feltiae*, biopesticides, pepper.

INTRODUCTION

Root-knot nematodes, *Meloidogyne* species (Goldei) are distributed all over the world; some species are found in tropical and subtropical areas in Africa such as in Egypt. Sasser, 1980 mentioned that *Meloidogyne* spp. cause serious problems to both the quantity and quality of field crops. *M. incognita* is more common in warm temperate, tropical and subtropical regions of the world and it is considered to be the most destructive pathogen in many crops (Taylor and Sasser,1978). *Meloidogyne* spp. has a wide host range of plant species including vegetables, ornamentals and even weeds. So, root-knot nematodes are considered polyphagous plant parasites attacking up to 5500 different high plant species (Trudgill and Blok, 2001). Vegetables production in tropical countries depends on the correct management of nematodes (Sikora and Fernandez, 2005). RKNs have a high reproduction rate, which results in the accumulation of large quantities of eggs in the soil (Campos *et al*., 2001) and are a major limitation to successful vegetable production all over the world, causing severe damage that leads to 10% of loss in yield (Sasser and Carter, 1985; Amin, 1993; 1994; Karssen and Moens, 2006).

In Egypt, both ecological and geographical conditions allow to produce good quality peppers (*Capsicum annuum* L.) in lot quantities, but root-knot nematodes *M. incognita* (Kofoid and White) Chitwood and *M. javanica* (Treub) Chitwood, are becoming real threats to almost all vegetable crops including pepper cultivars which are susceptible to *M. incognita* and considered as limiting factors in crop production particularly in the newly reclaimed sandy areas (Ibrahim, 1985).

Many control methods are applied to control or reduce the population of root -knot nematodes. Although the traditional method of nematode management by using chemical nematicides is the more effective, it has disadvantages such as high expensive and risk to human health as well as the environment. Thus, there is immediately needed to alter chemical control and encourage the scientists to search for natural compounds with less toxicity and eco-friendly alternative. Now, many diverse techniques are available, including biocontrol agents such as commercial products of entomopathogenic nematodes, bionematicides (Nema k & Nema clean) and plant oils which were found to possess nematicidal activity (Oka *et al*.,2000 and Cetinas *et al*.,2010).

Therefore, the aim of present study was to determine the effect of two entomopathogenic nematodes, two of plant extracts and two biopesticides as compared with chemical nematicides on *M. incognita* infecting three pepper cultivars under greenhouse conditions.

MATERIALS AND METHODS

Culturing of the root knot nematode:

Pure culture of *M. incognita*, was maintained in the greenhouse, Faculty of Agriculture, Zagazig University, Egypt on the tomato susceptible cultivar (Super Strain B) for using as source of inoculum. Species identification was based on juvenile measurements and examination of perineal pattern system of adult females according to Eisenback *et al*.,1981 and Jepson, 1987.

Source and culturing of entomopathogenic nematodes (EPNs):

Infective juveniles (IJs) of the tested nematode species were friendly obtained from Department of Entomology and Nematology, University of Florida, USA by Dr. Fahiem Elborai. The nematode species were *Heterorhabditis bacteriophora* and *Steinernema feltiae*. They were cultured separately in greater wax moth *Galleria mellonella* L. according to the technique of Dutkey *et al*. (1964). IJs emerged from cadavers were stored in distilled water at 12 °C for 1 week until applied in pots (Woodring & Kaya, 1988).

Plants culture:

Three pepper (*Capsicum annuum* L.) cultivars namely 1515 and Rima (Egypt) and Lama (Holland) were chosen in the present study because they severely attacked by *M.incognita* (Al-Sayed, el al., 1988; Zamora *et al,* 1994 and Fery & Dukes, 1996) besides regional economic importance.

Seeds of the tested pepper cultivars were soaked in sterile distilled water in Petri dishes and kept in an incubator at 26±1°C. After 48 hours, seeds were sown in clay pots (25-cm diameter) containing steam sterilized sandy soil. At the two-leaf stage, seedlings were singly transplanted to formalin sterilized 20-cm diameter plastic pots filled with steam sterilized sandy soil (95.7% sand; 1.2% silt and 3.1% clay).

Experimental design:

One week after transplanting, when seedlings were approximately 10 cm in height, they were inoculated with 1000 newly hatched IJs of *M.incognita* per plant. IJs were added by pipetting 2 ml of the inoculum suspension into three holes around the root system. Directly after inoculation the holes were covered with moist soil.

EPNs treatments (*Heterorhabditis bacteriophora* (HP88 strain) and *Steinernema feltiae*) were applied at the same time of nematode inoculation to tomato seedlings at concentration of alive 5000 IJs per seedling. IJs were placed on the soil surface in 2 ml water with a pipette.

The nematicide, oxamyl (Fydal 24% SL) at 0.2 ml per pot was applied instantly after *M.incognita* inoculation according to the recommended rate based on formulated form by incorporating the exact amount in the upper 3 cm of soil pot.

The bionematicides treatments Nema K (garlic extract , nitrogen and cytokinines) and Nema clean (*Serratia marcescens* , saponin and citric acid) were introduced to soil at the rate of 0.4 ml /plant. Control treatments included inoculation of *M. incognita* IJs alone as well as healthy plants without nematode inocula. For plant oil treatments, pots were treated by two different essential oils with concentration of 400 µL/plant after nematode inoculation. Each treatment was replicated three times. Common name and extraction methods of plant essential oils is shown in Table (1).

Table 1. The common name and extraction methods of plant essential oils used in the study

Extraction method	Plant parts	Scientific name	Common name
Steam distillation	Leaves	*Inula viscosa*	Aromatic inula
Steam distillation	Leaves	*Azadirachata indica*	Neem

All treatments were arranged in a randomized complete block design in the greenhouse at 26 ± 4°C., and all received similar horticultural treatments.

Plants were detached carefully from each pots after two months of nematode inoculation and data on plant growth (fresh weight of shoots and roots) were recorded. Roots and surrounding soil in the pots were soaked in clean water for 20 minutes to facilitate removing adhering soil and keep egg masses on root surface. Roots were wrapped in tissue paper to avoid drying out during the steps of evaluation. Number of galls and egg masses were counted per root system. Nematodes were extracted from soil using a combination of seiving and Baermann trays technique (Hopper *et al.* 2005). Moreover, fresh and dry weight of shoots were measured. Means were compared by Duncan's multiple range test at P ≤ 0.05 (Duncan, 1955).

RESULTS AND DISCUSSION

Data in Table (2) show the effect of two biopesticides (Nema k & Nema clean) , two plant oils (*Inula viscosa* & *Azadirachata indica*) and two of entomopathogenic nematodes (*Steinernema feltiae* & *Heterorhabditis bacteriophora*) compared to chemical nematicide, oxamyl on root- knot nematode, *Meloidogye incognita* infecting pepper plants (*Capsicum annuum* L.) cv. 1515 after two months of application.

Results indicated that all treatments significantly (P ≤ 0.05) reduced gall numbers as compared to control treatment. Pots treated with oxamyl overwhelmed those treated with biopesticides, plant extracts and EPNs in minimizing numbers of root-galls. Since maximum percentages of reduction were recorded when plants treated with oxamyl (92.17%) followed by *S. feltiae* (90.21%) and biopesticide, Nema clean (89.34%). It was evident that, oxamyl application suppressed root galls with insignificantly variations with EPNs, and biopesticides. On the other hand, high significantly differences were detected between oxamyl treatments compared with check treatment. However, the minimum percentage reduction was obtained in case of pots treated with *A.indica* (86.51%) followed by Nema k (87.39%).

Regarding the efficiency of the treated materials on egg masses, results clearly showed that oxamyl, and *S. feltiae* achieved the highest significantly effect in minifying numbers of egg masses compared to other materials. Whereas, *A. indica* achieved the lowest significantly effect compared to untreated plants. Percentages of reduction in egg masses for treated materials were 79.47, 70.19, 68.86, 65.56, 62.90 and 61.59% with oxamyl, *S. feltiae*, Nema clean, *I. viscosa*, Nema k and *A. indica*, respectively (Table 2).

On the other hand, statistical analysis showed that oxamyl ranked the first in decreasing number of *M. incognita* IJs followed by *S. feltiae*. Since number of IJs of *M. incognita* decreased to reach 9.00, 19.67, 20.67, 21.33, 23.33 and 24.67 with oxamyl, *S. feltiae,* Nema clean, *H.bacteriophora, I. viscosa* and Nema k, respectively. Whereas, *A. indica* (25.33) was the lowest effect in diminishing number of IJs.

For plant growth, all tested materials enhanced fresh and dry shoot weights of pepper plants to a certain extent as compared to check treatment. However, insignificant variations in shoot fresh weight were detected between most of the tested materials except oxamyl.

On the other hand, the curative application with oxamyl , Nema clean *S. feltiae, I. viscosa A. indica* and *H.bacteriophora* significantly promoted dry shoot weight compared with the control. Increase percentages were 47.11, 41.33, 40.41, 40.41, 37.87 and 38.79, respectively with abovementioned treatments. Regarding to fresh shoot weight, Nema clean (16.67%) determined the highest insignificantly effect with oxamyl (16.59%). whereas, the lowest increase in fresh shoot weight was achieved with *A. indica* (11.92%).

Table 2. Effects of bionematicides, plant oils ,entomopathogenic nematodes and oxamyl on fresh and dry shoot weights of pepper (*Capsicum annuum* L.) cv. 1515 and *Meloidogyne incognita* galling and reproduction.

Treatments	Concentration	Soil and root parameters			Plant Parameters	
		Number of galls/plant (Reduction %)	Number of egg masses/plant (Reduction %)	Number of IJs/100g (Reduction %)	Fresh shoot weight (g) (Increase %)	Dry shoot weight (g) (Increase %)
Healthy plants		0.00 d	0.00 h	0.00 g	17.31 a	6.82 a
Control (*M.incognita* alone)	1000 IJs	153.33 a	50.33 a	84.00 a	14.34 e	4.33 d
M.incognita + Oxamyl (Fydal 24% SL)	0.2 ml/ plant	12.00 c (92.17)	10.33 g (79.47)	9.00 f (89.28)	16.72 b (16.59)	6.37 b (47.11)
M.incognita + Nema K	0.4 ml /plant	19.33 bc (87.39)	18.67 bc (62.90)	24.67 bc (70.63)	16.32 cd (13.80)	6.06 c (39.95)
M.incognita + Nema clean	0.4 ml /plant	16.33 bc (89.34)	15.67 de (68.86)	20.67 d (75.39)	16.73 b (16.67)	6.12 c (41.33)
M.incognita + *I. viscosa*	25 0 µL/plant	18.67 bc (87.82)	17.33 cd (65.56)	23.33 bcd (72.22)	16.36 bcd (14.08)	6.08 c (40.41)
M.incognita + *A. indica*	25 0 µL/plant	20.67 b (86.51)	19.33 b (61.59)	25.33 b (69.84)	16.05 d (11.92)	5.97 b (37.87)
M.incognita + *S. feltiae*	5000 IJs /plant	15.00 bc (90.21)	15.00 e (70.19)	19.67 d (76.58)	16.43 bc (14.57)	6.08 c (40.41)
M.incognita + *H.bacteriophora* (HP88 strain)	5000 IJs /plant	17.67 bc (88.47)	17.67 bc (64.89)	21.33 cd (74.60)	16.30 cd (13.66)	6.01 c (38.79)

*** Each value is a mean of 3 replicates.**
*** Means in each column followed by the same letter(s) are not significantly different at P ≤ 0.05 according to Duncan's multiple range test.**

$$\text{Reduction } (\%) = \frac{\text{Control} - \text{Treated}}{\text{Control}} \times 100 \qquad \text{Increase } (\%) = \frac{\text{Treated} - \text{Control}}{\text{Control}} \times 100$$

Data revealed that all treated plants with either EPNs or oxamyl significantly reduced root galling when compared with inoculated-untreated pepper plants. Of the seven tested materials oxamyl, *S.feltiae* and *H.bacteriophora* were the most effective, whereas *A. indica* , *I.viscosa*, Nema clean and Nema k showed lowest effect on reducing root galling and number of egg masses of *M. incognita* infecting pepper cv. Rima (Table 3). Root galling and egg masses were evaluated on the basis of percentage reduction to the control. Oxamyl significantly gave high effect which recorded 87.71 % reduction in root galling followed by *S.feltiae* (74.73 %) then *H.bacteriophora* (67.33%), Nema clean (57.89%) and Nema k (45.26%). However, *A. indica* (38.60 %) as well as *I.viscosa* (40.70%) achieved the lowest effect on number of galls with insignificant between each other.

Table 3. Effects of bionematicides, plant oils, entomopathogenic nematodes and oxamyl on fresh and dry shoot weight of pepper (*Capsicum annuum* L.) cv. Rima (Egypt) and *Meloidogyne incognita* galling and reproduction.

Treatments	Concentration	Soil and root parameters			Plant Parameters	
		Number of galls/plant (Reduction %)	Number of egg masses/plant (Reduction %)	Number of IJs/100g (Reduction %)	Fresh shoot weight (g) (Increase %)	Dry shoot weight (g) (Increase %)
Healthy plants		0.00 i	0.00 g	0.00 g	13.89 a	5.06 a
Control (*M.incognita* alone)	1000 IJs	95.00 a	71.67 a	205.33 a	12.61 g	4.35 ef
M.incognita + Oxamyl (Fydal 24% SL)	0.2 ml/plant	11.67 h (87.71)	10.67 f (85.11)	21.00 f (89.77)	13.50 b (7.05)	4.86 b (11.72)
M.incognita + Nema K	0.4 ml /plant	52.00 c (45.26)	37.67 cd (47.43)	56.33 b (72.56)	12.83 efg (1.74)	4.48 de (2.98)
M.incognita + Nema clean	0.4 ml /plant	40.00 c (57.89)	33.33 de (53.49)	40.33 c (80.35)	13.01 de (3.17)	4.65 c (6.89)
M.incognita + *I. viscosa*	25 0 µL\plant	56.33 b (40.70)	44.33 bc (38.14)	55.67 b (72.88)	12.75 fg (1.11)	4.47 de (2.75)
M.incognita + *A.indica*	25 0 µL\plant	58.33 b (38.60)	49.33 b (31.17)	60.00 b (70.77)	12.63 g (0.15)	4.39 ef (0.91)
M.incognita + *S. feltiae*	5000 IJs /plant	24.00 f (74.73)	35.33 de (50.70)	26.00 ef (87.33)	13.11 cd (3.96)	4.60 cd (5.74)
M.incognita + *H.bacteriophora* (HP88 strain)	5000 IJs /plant	31.03 e (67.33)	39.33 cd (45.12)	34.67 cd (83.11)	12.94 def (2.61)	4.82 f (10.80)

*** Each value is a mean of 3 replicates.**
*** Means in each column followed by the same letter(s) are not significantly different at P ≤ 0.05 according to Duncan's multiple range test.**

$$\text{Reduction } (\%) = \frac{\text{Control} - \text{Treated}}{\text{Control}} \times 100 \qquad \text{Increase } (\%) = \frac{\text{Treated} - \text{Control}}{\text{Control}} \times 100$$

On pepper cv. Rima, there were no significant differences between biopesticides and EPNs treatments in egg masses reduction but significantly exceed those in the control. The percentage of reduction in egg masses for oxamyl, Nema clean and *S.feltiae* were 85.11, 53.49 and 50.70%, consequently.

On the other hand, the highest number of IJs /100 g soil was recorded in inoculated-untreated plants (205.33). Pots receiving oxamyl, biopesticides and EPNs showed significantly ($P \leq 0.05$) fewer number of IJs compared to plant oils (*A. indica* and *I.viscosa*). The least number of IJs /100 g was recorded for oxamyl treated pepper plants

(21.00) which were significantly lower than those of entomopathogenic nematodes (*S.feltiae* and *H.bacteriophora*) treated plants (26.00 and 34.67, respectively).

Application with the tested materials slightly enhanced fresh and dry shoot weight of pepper plants compared with the control. The curative application with oxamyl (7.05%), *S. feltiae* (3.96%), Nema clean (3.17%), *H.bacteriophora* (2.61%), Nema k (1.74%) and *I. viscosa* (1.11%) increased fresh shoot. Whereas, *A. indica* achieved the least increase percentage (0.15). Regarding to dry shoot weight, oxamyl (11.72%) achieved the highest effect followed by *H.bacteriophora* (10.80%). Whereas, the lowest increase was achieved with *A. indica* (0.91).

Data in Table (4) clearly showed that oxamyl proved to be the most suppressive one on *M. incognita* infecting pepper plants (*Capsicum annuum* L.) cv. Lama (Holland) and recorded 88.41% reduction in root galling followed by *S.feltiae* (74.67%) then *H.bacteriophora* (72.53%). However, EPNs and biopesticides followed oxamyl of percentage reduction in egg masses and achieved high effect with percentage 64.56, 58.25, 63.78 and 55.89 for *S.feltiae*, *H.bacteriophora*, Nema clean and Nema k, respectively. However, plant extract, *A. indica* achieved the lowest effect with percentages of reduction 54.33% in egg masses.

In pepper cv. Lama (Holland), infected with *M. incognita* the highest number of IJs /100 g soil was recorded in inoculated-untreated plants (131.33). Pots treated with oxamyl, biopesticides and EPNs showed significantly ($P \leq 0.05$) fewer numbers of IJs compared to plant oils (*A. indica* and *I.viscosa*).

Obviously, all tested materials were found to enhance fresh and dry shoot weights of pepper plants cv. Lama much greater than those of cv. Rima. Next to oxamyl, EPNs (*S.feltiae* & *H.bacteriophora*) showed better performance in promoting fresh shoot weight than did the biopesticides (Nema clean and Nema k). Application with oxamyl, *S. feltiae* and Nema clean increased fresh shoot to reach 11.48, 9.74 and 9.47%, respectively. Whereas, *A.indica* achieved the least increase percentage (7.14%). However, curative application with oxamyl, Nema clean and *S. feltiae* increased dry shoot to reach 32.70, 27.50 and 26.68%, respectively. Whereas, *A.indica* achieved the least increase percentage (24.37%).

Table 4. Effects of bionematicides, plant oils, entomopathogenic nematodes and oxamyl on fresh and dry shoot weight of pepper (*Capsicum annuum* L.) cv. Lama (Holland) and *Meloidogyne incognita* galling and reproduction.

Treatments	Concentration	Soil and root parameters: Number of galls/plant (Reduction %)	Soil and root parameters: Number of egg masses/plant (Reduction %)	Soil and root parameters: Number of IJs/100gm (Reduction %)	Plant Parameters: Fresh shoot weight (g) (Increase %)	Plant Parameters: Dry shoot weight (g) (Increase %)
Healthy plants		0.00 i	0.00 g	0.00 g	17.49 a	7.76 a
Control (*M.incognita* alone)	1000 IJs	77.67 a	42.33 a	131.33 a	14.98 e	4.80 d
M.incognita + Oxamyl (Fydal 24% SL)	0.2 ml/plant	9.00 e (88.41)	10.33 f (75.59)	12.00 d (90.86)	16.70 b (11.48)	6.37 b (32.70)
M.incognita + Nema K	0.4 ml /plant	24.67 b (68.23)	18.67 b (55.89)	19.33 bc (85.28)	16.32 cd (8.94)	6.06 bc (26.25)
M.incognita + Nema clean	0.4 ml /plant	26.67 bc (65.62)	15.33 cd (63.78)	16.33 bcd (87.56)	16.40 bc (9.47)	6.12 bc (27.50)
M.incognita + *Inula viscosa*	25 0 µL\plant	23.33 bc (69.96)	17.33 bc (59.05)	18.67 bc (85.78)	16.36 c (9.21)	6.08 bc (26.66)
M.incognita + *Azadirachata indica*	25 0 µL\plant	25.33 b (67.38)	19.33 b (54.33)	20.67 b (84.26)	16.05 d (7.14)	5.97 c (24.37)
M.incognita + *S. feltiae*	5000 IJs /plant	19.67 cd (74.67)	15.00 d (64.56)	15.00 cd (88.57)	16.44 bc (9.74)	6.09 bc (26.68)
M.incognita + *H.bacteriophora* (HP88 strain)	5000 IJs /plant	21.33 bc (72.53)	17.67 b (58.25)	17.67 bc (86.54)	16.30 cd (8.81)	6.01 bc (25.20)

*** Each value is a mean of 3 replicates.**
*** Means in each column followed by the same letter(s) are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.**

$$\text{Reduction } (\%) = \frac{\text{Control - Treated}}{\text{Control}} \times 100 \qquad \text{Increase } (\%) = \frac{\text{Treated - Control}}{\text{Control}} \times 100$$

DISCUSSION

In vegetable crops, traditional methods used to control plant–parasitic nematodes especially, root knot nematode, *M. incognita*, based on the use of chemicals pesticides which not economical in the long run, in addition to polluting the air, soil, and environment (Naseby *et al.*, 2000). In this aspect, the main objective of this paper was to compare the effect of non-chemical products such as biopesticides (Nema clean & Nema k), entomopathogenic nematodes (*S.feltiae* & *H.bacteriophora*) and plant oils (*A. indica* and *I.viscosa*) as alternatives to chemical pesticides for their effectiveness in suppressing root knot nematode, *M.incognita* infecting three cultivars of pepper plant.

Different biological agents are used to control root-knot nematodes such as bacteria and fungi (Siddiqui *et al.*, 2000 and Goswami & Mittal, 2004). A commercial suspension of *Serratia marcescens* (Nemaless) significantly decreased development and reproduction of *M.incognita* infecting tomato plant (Abd-Elgawad & Kabeil, 2012 and Raddy *et al*, 2013). These results support our findings of that Nema clean (*S.marcescens*) significantly suppressed root galling and number of egg masses and IJs of *M.incognita* infecting three tested cultivars of pepper. Furthermore, these results are in conformity with those reported by many authors who tested biopesticides against *Meloidogyne* spp. in *vitro* and in *vivo* assays (Goswami *et al.*, 2006; Mohamed *et al.*, 2009 and Yankova *et al.*, 2014).

In our study entomopathogenic nematodes, *S.feltiae* ranked next to oxamyl in suppressing *M. incognita* infecting pepper cultivars i.e. 1515, Rima and Lama. These results confirmed with those reported by many authors who observed suppressive effects of EPNs against root-knot nematodes under laboratory and greenhouse conditions (Bird & Bird, 1986; Grewal *et al*., 1999; Perez and Lewis, 2004; Aatif *et al*.,2016 and Khan *et al*., 2016). Moreover, suppressive effects of EPNs have been demonstrated on other plant parasitic nematodes (PPNs) under field conditions like *Tylenchorhynchus* spp. and *Pratylenchus penetrans* (Smitley *et al*.,1992), *Belonolaimus longicadatus* and *Criconemoides* spp. (Grewal *et al*., 1997), *Globodera rostochiensis* (Perry *et al*., 1998) and *Nacobbus aberrans* (Caccia *et al*.,2013). Lewis and Grewal (2005) reported that in some cases the use of EPNs does not always reduce PPN populations and the effects of their interaction vary with EPN and PPN species, the host crop and the impact on PPNs.

The suppressive effects of EPNs on PPNs may be attributed to many factors. Fore instances, attraction of *S.glaseri* to tomato roots and suppression may be due to rivalry between the two nematode groups for space (Bird and Bird , 1986); increase density of predators resultant from the application of nematode biomass to the soil (Ishibashi and Kond,1986), production of allelochemicals of EPN symbiotic bacteria complex (Grewal *et al*.,1999; Hu *et al*., 1999 and Lewis *et al*., 2001) and use infective juveniles of *S. carpocapsae* and its symbiotic bacteria (*X. nematophilus*) stimulated the activity of P-peroxidase ,G- peroxidase and catalase enzymes which are responsible for inducing systemic resistance in plants (Jagdale *et al*., 2009).

Our results showed that, *S.feltiae* was more effective than *H.bacteriophora* in controlling *M. incognita* infecting pepper. It may be due to the ability of *Steinernema* spp. to enter host roots and release their symbiotic bacteria which produce allelochemicals that are toxic or repellent to *M. incognita* (Grewal *et al*.,1999). Also, Steinernematidae (*S.feltiae* and *S. riobravae*) but not Heterorhabditidae (*H.indica*) were found intercellular in the root cortex of soybean plants that had been infected with RKN (Fallon *et al*., 2002). Moreover, El-Ashry *et al.* (2018) showed that EPNs belonging to steinernematids were more effective than those belonging to heterorhabditids in controlling *M. incognita* infecting tomato.

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تأثير استخدام بعض زيوت المستخلصات النباتية ، وعوامل المكافحة البيولوجية والكيماوية على التعقد والتكاثر لنيماتودا تعقد الجذور *Meloidogyne incognita* التي تصيب أصناف الفلفل

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أجريت تجربة تحت ظروف الصوبة لتقييم إثنين من المبيدات الحيوية (Nema clean& Nema k), وإثنين من الزيوت النباتية *Inula viscosa* & (*Azadirachata indica*) واثنين من النيماتودا الممرضة للحشرات (*Steinernema feltiae* & *Heterorhabditis bacteriophora*) كمبيدات نيماتودية ضد نيماتودا *Meloidogyne incognita* التي تصيب ثلاثة من أصناف الفلفل (*Capsicum annuum* L.) مقارنة مع مبيد الأوكساميل oxamyl . واستخدمت المبيدات الحيوية بمعدل ٠.٤ مل/ نبات بينما استخدمت المستخلصات النباتية بمعدل ٤٠٠ مل ميكرون/ نبات واستخدمت نيماتودا الحشرات في صورة معلق مائي يحتوى على يرقات الطور المعدي في صورة حية بمعدل ٥٠٠٠ طور يرقى/ نبات، وفي كل المعاملات استخدمت المواد المختبرة في نفس التوقيت مع إجراء العدوى بنيماتودا تعقد الجذور، كما استخدم الاوكساميل كمبيد نيماتودى بالتركيز الموصى به (٠.٢ مل/نبات) للمقارنة وأجريت العدوى لنباتات المعاملة الضابطة الموجبة بمعدل ١٠٠٠ يرقة/ نبات في حين تركت نباتات المعاملة الضابطة السالبة بدون أي إضافات، وبعد شهرين من المعاملة تم تقييم درجة التعقد (المشار إليها بعدد العقد/ نبات) والتكاثر (المشار إليه بعدد كتل البيض/ نبات) بالإضافة إلى الضرر (المشار إليه بالوزن الطازج والجاف لأجزاء النبات الخضرية). أوضحت النتائج أنه من بين كل المواد المختبرة, كان الاوكساميل والمبيدات الحيوية والنيماتودا المتطفلة على الحشرات كانت الأكثر فاعلية في خفض كل من العقد المتكونة على الجذر وعدد كتل البيض التي تكونها نيماتودا نعقد الجذور *M.incognita* على نباتات الفلفل. فى حين كانت الزيوت النباتية أقل المواد المختبرة فاعلية. وكان الأوكساميل الأعلى تأثيرا فى خفض العقد الجذرية وكتل البيض بنسبة (٩٢.١٧ & ٧٩.٤٧ %) يليه نيماتودا الحشرات *S. feltiae* (٩٠.٢١ & ٧٠.١٩ %) ثم المبيد الحيوى Nema clean (٨٩.٣٤& ٦٨.٨٦ %) على الصنف ١٥١٥ ومن ناحية أخرى ، حقق الأوكسامل المرتبة الأولى في خفض أعداد الطور المعدى لنيماتودا تعقد الجذور مع الثلاثة أصناف من الفلفل. وبالنسبة لنمو نباتات الفلفل ، حققت المعاملات العلاجية بكل من الأوكساميل و Nema clean أقصى نسبة مئوية للزيادة فى الوزن الطازج (٤٧.١١& ٤١.٣٣) والوزن الجاف (١٦.٥٩ &١٦.٦٧)، على التوالي للمجموع الخضرى في نباتات الفلفل وعلى صنف Rima ، إحتل الاوكساميل المرتبة الأولى يليه نيماتودا الحشرات *S. feltiae* فى خفض العقد الجذرية وكتل البيض ومع هذا ، حقق الاوكساميل المرتبة الأولى مع الصنف Lama ، في خفض العقد الجذرية وكتل البيض ، وأيضا أعلى زيادة في الوزن الطازج والجاف (١١.٤٨ & ٣٢.٧٠ %) يليه Nema clean (٩.٤٧ & ٢٧.٥٠ %) للمجموع الخضري في نباتات الفلفل.