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Evaluation of some non-fumigant nematicides and the biocide avermactin for managing *Meloidogyne incognita* in tomatoes

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Abstract

A pot experiment was conducted to evaluate the efficacy of avermactin a new bio-nematicide in Egypt, in comparison with five non-fumigant nematicides namely, cadusafos, ethoprophos, fenamiphos, fosthiazate and oxamyl for managing the root-knot nematode, *Meloidogyne incognita* in tomatoes based on number of galls per root system, number of egg-masses, eggs per egg-mass and number of juveniles (J_2) in the soil as well as plant growth characteristics. All nematicidal treatments reduced the incidence of root-knot nematodes when compared with the untreated check. However, fenamiphos and oxamyl were proved to be the highest chemical compostions that decreased galls by 91.73 and 89.53% and egg-masses by 90.80 and 88.65%, respectively. Whereas, avermactin has relatively least effective causing 66.69% and 66.31% reduction in gall formation and egg-masses, respectively. Meanwhile, cadusafos and oxamyl achieved the greatest reduction for eggs per egg-mass by 68.26 and 63.17%, consecutively. As for eggs per egg-mass, avermactin provided 16.34% reduction. All the tested nematicides significantly reduced the population of J_2 in the soil ranging from 69.49 to 90.31 %. Also, all applied treatments enhanced tomato growth indices as compared to the untreated inoculated control.

Keywords: Non-fumigant nematicides, avermactin, *Meloidogyne incognita*, tomato.

Tomato (*Lycopersicon esculentum* Mill.) is one of the most common and important vegetable crops in the world. Yield losses of tomatoes are due to diseases caused by bacterial, fungal, viral and nematode pathogens. It is estimated that plant parasitic nematodes cause annual loss of US$157 billion globally (Abad *et al*., 2008). Among plant parasitic nematode, root-knot nematodes (*Meloidogyne* spp.) are widespread and recognized as a damaging pathogen of tomato that causes more than 27% yield losses (Sharma & Sharma, 2015). In addition, their infestations on tomato are common in Egypt as well; causing high crop damage especially in sandy soil and reclaimed desert lands (Ibrahim *et al*., 2010 a). *Meloidogyne incognita* is considering the most widespread species of this genus. Although *Meloidogyne* management is extremely difficult due to their wide range of the hosts, short periods of high reproductive rate and generation (Trudgill & Block, 2001).

A variety of management strategies including chemical nematicides, cultural practices, solarization, crop rotation, biological control, resistant cultivars and organic soil amendments have been considered effective for reducing nematode damage on various crops (Sikora & Fernandez, 2005). Application of chemical nematicides is the most widely used strategy and quick solution for the problem caused by plant parasitic nematodes, especially in intensive production systems involving high-value crops (Haydock *et al*., 2006).

The most widely used non-fumigant nematicides in vegetable production are the carbamates and organophosphates (Rich *et al*., 2004). It was accepted that the toxic effect of these compounds acted by the inhibition of acetylcholinesterase (AChE) at cholinergic synapses in the nematode nervous system. Inhibition of AChE was most likely explanation for the observed effect of the main two groups of nematicides on the orientation behavior of nematodes (Opperman & Chang, 1990).

Abamectin is a natural fermentation product of the soil bacterium, *Streptomyces avermitilis*. It is the mixture of Avermactins, which is a new generation of pesticides, represents new trend in the field of plant parasitic nematodes management. The mode of action of abamectin is associated with its effect on the δ-aminobutyric acid (GABA) receptors and glutamate-gated chloride channels increasing the permeability of chloride ions, hyperpolarizing the nerve and muscle cells, and disturbing the neuromuscular transmission leading to death (Martin *et al.*, 2002). Certain reports unanimously recorded that abamectin has nematicidal action against root-knot nematodes and other genus in different crops (Faske & Starr, 2007; Ibrahim *et al*., 2010b; Saad *et al*., 2012).

Therefore, the objective of the present study was aimed to evaluate the efficacy of avermactin as a newly registered bionematicide in Egypt, in comparison with some non-fumigant nematicides for the management of *M. incognita* infecting tomato plants.

Materials and Methods

Nematode inoculum: The egg inoculum was isolated from infected root of tomato plants (cv. Golden Stone). The roots were cut into small segments (1–2 cm long), then shacked for 3 min in 5% sodium hypochlorite (NaOCl). The suspension was passed through 200 and 400 mesh sieves to obtain free eggs (Hussey & Barker, 1973). The eggs were washed several times with water and their counts were estimated under a stereo-microscope. Moreover, the identification of the species for the root-knot nematode (*Meloidogyne incognita*) was carried out by using the perineal patterns method according to Taylor & Nelscher (1974).

Pot experiment: A pot experiment was executed to evaluate the efficacy of avermactin, cadusafos, ethoprophos, fenamiphos, fosthiazate and oxamyl against *M. incognita* on tomato plants. All plastic pots of 15 cm diameter filled with 1 kg of loamy sand soil (76 % sand, 14 % silt and 10 % clay, pH 8.6, 1.02 % organic matter). One plantlet of *Solanum lycopersicum* L. cv. ELISA of 40 days old was transplanted in each pot. The nematicides were applied as soil drench based on the formulated form at the field dosage rate (Table 1), which recommended by the Agricultural Pesticide Committee, Ministry of Agriculture and Land Reclamation, Egypt, after 3 days from inoculation time. Each pot was inoculated with 5000 nematode eggs after four days from transplanting time by pouring the nematode suspension into holes made 2-4 cm below the soil surface around the base of the plants. All pots including controls (inoculated and uninoculated plants) were replicated five times and arranged in a complete randomized design on a bench in outdoor conditions. During the course of the experiment, the irrigation and fertilization were made when needed.

After 60 days from inoculation time, plants were uprooted and the roots were washed free of soil. The shoot and root lengths, in addition to their dry weights were recorded. Furthermore, number of galls / root system, egg-masses, eggs/ egg-mass and number of J_2 / 250 g soil were estimated. The second stage juveniles (J_2) were extracted from the soil by using sieving and Baermann plate technique (Ayoub, 1980) and counted. For the egg-masses count, they were first stained by dipping the roots in an aqueous solution of phloxine B (0.15 g/L water) for 15 minutes and then washed with running water to remove excess stain (Holbrook *et al*., 1983).

Statistical analysis: Data of the present study were subjected to the analysis of variance test (ANOVA) as complete randomized design (CRD). The least significant differences (LSD) at the 5% level of probability were determined using a computer program CoStat Version: 6.303 (1998).

Results and Discussion

The obtained results show that tomato root galling was significantly reduced by all applied treatments compared to untreated check (Table 2). Fenamiphos (91.73%) and oxamyl (89.53%) had possessed the best effectiveness in controlling *M. incognita* in tomato based on root galling. While ethoprophos, cadusafos, avermactin and fosthiazate, reduced galls by 83.23, 74.20, 66.69 and 63.81%, respectively, and were in the next category.

Fenamiphos, oxamyl and ethoprophos gave the highest reductions of egg-masses by 90.80, 88.65 and 81.00%, respectively. Whereas, fosthiazate, avermactin and cadusafos were relatively less effective, causing 67.50, 66.31 and 66.19%, respectively. All treatments reduced the number of eggs per egg-mass and the reduction percentages ranged from 16.34 to 68.26%, whereas cadusafos gave the highest reduction (68.26%) and avermactin recorded the least one (16.34%).

It was noticed that all the tested treatments significantly diminished J_2 population in the soil when tested at the recommended dosage rate (which were not equal) compared to the untreated check. However, fosthiazate, fenamiphos and oxamyl were found to be effective treatments, which reduced J_2 in the soil by 90.31, 87.81 and 83.92%, respectively. Otherwise, ethoprophos, avermactin and cadusafos occupied the second rank in suppressing J_2, which accounted 75.90, 75.34 and 69.49% reduction, respectively (Table 2).

In our investigation, all of the tested nematicides show higher nematicidal action against *M. incognita* than that of the bionematicide, avermactin based on the reduction of galls/root system, number of J_2 in soil, number of egg-masses/root and number of eggs/egg-mass. The data on the efficacy of the non-fumigant nematicides may be compared in relation to the doses used for each nematicide. Fenamiphos, oxamyl and ethoprophos occupied the first rank in decreasing the incidence of root-knot disease caused by *M. incognita*. These results are in conformity with data obtained by Acosta *et al*., (1987) who showed that fenamiphos and oxamyl, had the maximum reduction in *M. incognita* eggs and population of J_2 in the soil. Recently, Kimenju *et al*., (2014) found that fenamiphos was a superior treatment which significantly reduced gall index, egg-masses in carnation and population of J_2 in the soil. Mostafa *et al*., (2015) reported that the tested commercial oxamyl products gave the best result in reducing root-knot nematodes on potato plants.

On the other hand, cadusafos, avermactin and fosthiazate occupied the second rank in suppressing *M. incognita* infecting tomato. Several authors reported that the above mentioned nematicides which already used in the present study were effective against the root-knot nematode, *Meloidogyne* spp. with different levels of success. Giannakou *et al*., (2005) mentioned that oxamyl provided some nematode control while cadusafos unsuccessful to provide adequate nematode control, which may be credited to the inability of the nematicide to reduce nematode populations even at relatively high concentrations in soil. Furthermore, fosthiazate and cadusafos proved to be active against J_2 of *M. incognita* and the number of tomato galls (Saad *et al*., 2012). Similarly, Radwan *et al*., (2012) also tested various granular nematicides against *M. incognita* on tomato and found that fosthiazate had the highest nematicidal effect with 97.52% reduction in galls and 96.45% juveniles in soil, while cadusafos was relatively least effective causing 77.51 and 86.63% reduction in galling and J_2 population, respectively. On the contrary, cadusafos was found to be superior in reducing the incidence of root-knot nematodes infecting different vegetable crops (Meher *et al*., 2010; Raddy *et al*., 2013). In addition to their AChE inhibitors, it might be concluded from our study that these non-fumigant nematicides acted against the root-knot nematode by inhibiting egg hatching, their movement and host invasion by infective juveniles and checked further development of second stage juveniles that had penetrated the roots (Bunt, 1987).

Among the tested nematicides, avermactins had relatively least effective compound against *M. incognita* infecting tomato. The literature survey showed that avermactin was found to be effective against root-knot nematodes, *Meloidogyne* spp., on rape seed (Korayem *et al*., 2008), tomato (Khalil *et al*., 2012), cucumber (Huang *et al*., 2014) and date palm (El-Nagdi *et al*., 2015). However, Lopez-Perez *et al.*, (2011) found Avid® (abamectin) to be inconsistent in controlling root-knot nematodes on soil-grown tomato. They attributed this to the strong adsorption of abamectin to soil particles. No significant differences between some abamectin treatments and the untreated check in controlling root-knot nematodes in tobacco were observed by Muzhandu *et al*., (2014). They might also be attributed this to the immobility of abamectin in soil. Another factor affecting its effectiveness against root-knot nematodes is the timing of abamectin application. The abamectin treatments were only effective when applied at the same time as plants were inoculated with the root-knot nematode eggs (Lopez-Perez *et al.*, 2011). This finding could be a reasonable explanation for the outcome of our study where avermactin had relatively low efficacy against *M. incognita* on tomato. The growth performances (length and dry weight of shoots and roots) of tomato plants due to the application of avermactin in comparison with some non-fumigant nematicides are presented in Table (3). Data showed that, in untreated plants, *M. incognita* reduced plant growth parameters compared to nematode-free plants. Avermactin, oxamyl and fenamiphos significantly increased the shoot and root lengths as compared with the untreated inoculated control. Whereas fosthiazate, ethoprophos and cadusafos did not significantly differ from the untreated inoculated control in this respect. Except for ethoprophos and cadusafos, the other treatments significantly increased shoot dry weight compared to the untreated inoculated plants. However, avermactin was the superior treatment that increased shoot dry weight by 114.82% over untreated inoculated plants. Significant increases in root dry weight occurred in fenamiphos and oxamyl treatmentsas compared with the untreated inoculated control. While the rest tested treatments did not significantly differ from the untreated inoculated control (Table 3).

These findings are in agreement with the results of Ibrahim *et al*., 2010 b) who found that oxamyl and fosthiazate significantly increased the length and weight of tomato shoot system. Besides, our results are at par with the data obtained by several scientists; Radwan *et al*., (2012), Raddy *et al*., (2013) and Mostafa *et al*., (2015). They indicated that some non-fumigant nematicides enhanced plant growth criteria. Also, numerous reports have recently been confirmed that abamectin improved plant growth of different crops (Saad *et al*., 2012; Muzhandu *et al*., 2014).

Up to now the control strategy against root-knot nematodes in Egypt is based on chemical nematicides and a few products of bio-nematicides. Nevertheless, until the biologically based management system was more developed, the chemical nematicides tested will likely continue to be used whether as part of an integrated management programme or as the sole control component.

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Table 1. List of commercial nematicides tested in the present study.

Common name	Trade name	Formulation	Rate of application	Dosage (g or ml/pot)
Avermactin	Tervigo®	2% SC	2.5 L/ feddan	0.0025
Fosthiazate	Nemathorin®	10% G	12.5 Kg/ feddan	0.0125
Oxamyl	Vaydet®	10% G	20 Kg/ feddan	0.02
Fenamiphos	Nemafose®	40% EC	3 L /feddan	0.003
Ethoprophos	Nemagold®	10% G	30 Kg/ feddan	0.03
Cadusafos	Rugby®	10% G	24 Kg / feddan	0.024

Table 2. Effects of some non-fumigant nematicides and the biocide avermactin on *Meloidogyne incognita* infecting tomato in a pot experiment.

Treatments	Galls / root system		Egg-masses / root system		Eggs / egg-mass		J_2 / 250g soil	
	Mean	% Red	Mean	% Red	Mean	% Red	Mean	% Red
Untreated check	263.60 a	--	167.40 a	--	530.00 a	--	1180.0 a	--
Avermactin	87.80 b	66.69	56.40 b	66.31	443.40 b	16.34	291.00 c	75.34
Fosthiazate	95.40 b	63.81	54.40 b	67.50	402.00 b	24.15	114.40 e	90.31
Oxamyl	27.60 de	89.53	19.00 cd	88.65	195.19 de	63.17	189.80 d	83.92
Fenamiphos	21.80 e	91.73	15.40 d	90.80	215.82 d	59.28	143.80 de	87.81
Ethoprophos	44.20 d	83.23	31.80 c	81.00	304.00 c	42.64	284.40 c	75.90
Cadusafos	68.00 c	74.20	56.60 b	66.19	168.20 e	68.26	360.00 b	69.49
L.S.D. $_{0.05}$	18.13	--	12.96	--	46.11	--	56.26	--

Mean in each column followed by the same letter(s) did not significantly differ according to LSD (p = 0.05).

Table 3. Influence of some non-fumigant nematicides and the biocide avermactin on the growth parameters of tomato plants infected with *Meloidogyne incognita* in a pot experiment.

Treatments	Growth indices							
	Shoot system				Root system			
	Length (cm)		Dry weight (g)		Length (cm)		Dry weight (g)	
	Mean	Increase*	Mean	Increase*	Mean	Increase*	Mean	Increase*
Nematode	21.9 abc	15.26	1.02 a	88.89	21.30 abc	21.02	0.39 ab	77.27
Untreated	19.0 c	--	0.54 b	--	17.60 d	--	0.22 cd	--
Avermactin	23.8 ab	25.26	1.16 a	114.82	23.70 a	34.66	0.31 bcd	40.91
Fosthiazate	22.4 abc	17.89	1.07 a	98.15	17.20 d	-2.27	0.31 bcd	40.91
Oxamyl	24.9 a	31.05	1.03 a	90.74	22.30 ab	26.70	0.33 abc	50.00
Fenamiphos	23.6 ab	24.21	1.05 a	94.44	21.20 abc	20.45	0.43 a	95.46
Ethoprophos	20.8 bc	9.47	0.73 b	35.19	18.80 cd	6.82	0.25 cd	13.64
Cadusafos	22.5 abc	18.42	0.68 b	25.93	19.20 bcd	9.09	0.29 cd	31.82
L.S.D. $_{0.05}$	3.71	--	0.20	--	3.20	--	0.10	--

Mean in each column followed by the same letter(s) did not significantly differ according to LSD (p = 0.05).
*= values are in percentage

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