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POTENTIAL OF NON-FUMIGANT NEMATICIDES AT DIFFERENT FORMULATIONS AGAINST SOUTHERN ROOT-KNOT NEMATODE (*MELOIDOGYNE INCOGNITA*) ON TOMATO PLANTS

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ABSTRACT

Currently, plant parasitic nematodes (PPN) especially root knot nematodes, *Meloidogyne* spp. have been found involved in the global losses of tomato crops. The most employed tactic for managing PPN in Africa is non-fumigant nematicides. Recently, in Egypt abamectin was recorded as a new tool to control PPN. Thus, two pot experiments were conducted to evaluate the potential of abamectin and certain non-fumigant nematicides namely; oxamyl and ethoprophos at two different formulations (granular and liquid) against southern root knot nematode (*Meloidogyne incognita*) on tomato plants under greenhouse conditions. Results revealed the granular formulations of ethoprophos and oxamyl, in addition to abamectin, showed the same significance ($P \leq 0.05$) in suppressing tomato soil population and root galls of *M. incognita*, during both experiments. However, liquid formulations of ethoprophos and oxamyl gave relatively less decreasing in soil population and root galls. On the other hand, all applied treatments improved plant growth criteria ranging from 36.92 to 126.44% in shoot dry weight and from 31.25 to 137.50% in root dry weight for both experiments.

Keywords: Nematicides, Abamectin, *Meloidogyne incognita*, pesticides formulation.

INTRODUCTION

In recent years, plant parasitic nematodes, especially root knot nematodes have been found involved in the global losses of tomato crops (Luc *et al.*, 2005). The globally estimated yield losses of tomato plants due to root knot nematodes were reached up to 27% and more (Sharma and Sharma, 2015). In Egypt, root-knot nematodes, *Meloidogyne* spp., are the real threats to almost all vegetable crops and are becoming a limiting factor in crop production (Ibrahim, 2011).

The most employed strategy in Africa and worldwide to control plant parasitic nematodes (PPN) are non-fumigant nematicides. The majority of these nematicides are belonging to organophosphate and carbamate groups. These groups are diffuse because of their higher efficacy, easy to apply and achieve quick response on targeted pests (Raddy *et al.*, 2013). Ethoprophos (Mocap®) is belonging to the organophosphate group and work as systemic insecticide and nematicide. It could be used as soil application. Otherwise, oxamyl (Vydate®) is a

carbamate that has insecticidal and nematicidal properties. Also, oxamyl is not only systemic but also contact nematicide which can be used as foliar or soil drench. However, non-fumigant nematicides have higher costs, limited availability in certain developing countries or in some times have to repeat application (Ahmad and Siddiqui, 2009). Hence, alternative sources to control PPN are needed.

One of the new alternative tools for managing PPN is avermectins group which has been used extensively as anti-parasites in veterinary medicine and as pesticides in agriculture and horticulture (Tatsuta, 2015). Abamectin, belongs to macrolide metabolites is produced by the bacterium *Streptomyces avermectinius* (formerly, *S. avermitilis*) (Khalil and Abd El-Naby, 2018). The nematicidal activity of abamectin against different genera of PPN was documented in certain investigations (El-Nagdi and Youssef, 2004; Huang *et al.*, 2014; El-Nagdi *et al.*, 2015; Radwan *et al.*, 2019). Therefore, in the present study, we aimed to evaluate the potential of abamectin as

a newly registered nematicide in comparison with different common formulations (granular and liquid) of conventional non-fumigant nematicides namely; ethoprophos and oxamyl against southern root-knot nematode (*Meloidogyne incognita*) on tomato plants in pot experiments under greenhouse conditions.

MATERIALS AND METHODS

Nematicides Used: Five nematicides viz., abamectin (Tervigo® 2% SC), ethoprophos (Mocap® 10 % G and Nemacap® 20% EC) and oxamyl (Vydate® 10 % G and Fedal® 24% SL) were used in the present study. The liquid formulations such as abamectin were added at the rate of 2.5 L / Feddan (Recommended by Ministry of Agriculture), ethoprophos at the rate of 2.5 L / 100 L water and oxamyl at the rate of 2.5 L / 100 L water. However, the granular formulation of ethoprophos was added at the rate of 30 kg/ Feddan (4200 m²) and oxamyl at the rate of 25 kg / Feddan.

Nematode inoculum: The southern root-knot nematode, *Meloidogyne incognita* population was isolated from infected roots of eggplant (*Solanum melongena* L.) obtained from El-Nubaryia region, Beheira Governorate, Egypt. This species was recognized as *Meloidogyne incognita*, by using female perineal patterns method according to Netscher and Taylor (1974). The eggs of root knot nematode (*M. incognita*) were extracted by the sodium hypochlorite method from infested roots (Hussey, 1973).

Pot experiments: Two pot experiments were carried out to assess the impact of abamectin and two different formulations of ethoprophos and oxamyl against *M. incognita* on tomato plants. All plastic pots of 15- cm diameter filled with 1 kg of sterilized sandy loam soil. Each pot was transplanted with one tomato seedling (*Solanum lycopersicum* L. hybrid GS) of five weeks- old. Each pot was inoculated with 5000 nematode eggs after three 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. The nematicides were applied to the soil at the recommended rates after 2 days from nematode inoculation time. All pots were replicated five times and arranged in a complete randomized design on a bench in a greenhouse at 29-35 °C. The irrigation and fertilization were applied when appropriate. The nematicides were applied to the soil at the recommended doses after 2 days from inoculation time.

After 50 days from inoculation time, plants were

uprooted from the pots and the roots were washed free of adhering soil. In the termination of the experiments, the dry weights of shoot and root, the number of galls/root system and the number of J₂ / 250 g soil were evaluated. The second stage juveniles (J₂) were extracted from the soil by using sieving and Baermann plate technique and counted (Ayoub, 1980). The reductions (%) in soil population and root galls were calculated by the following formula:

$$\text{Reduction (\%)} = \left(\frac{\text{Control} - \text{Treatment}}{\text{Control}} \right) \times 100$$

Furthermore, the increases (%) in shoot and root dry weights were calculated by the next formula:

$$\text{Increase (\%)} = \left(\frac{\text{Treatment} - \text{Control}}{\text{Control}} \right) \times 100$$

Statistical analysis: Data obtained were statistically analyzed according to CoStat Software (2005) Version: 6.303. Results of the present work were subjected to the analysis of variance test (ANOVA) as complete randomized design (CRD). Comparison among means was made via the least significant difference (LSD) test at the 5% level of probability.

RESULTS AND DISCUSSION

The impact of abamectin as well as two different formulations (granular and liquid) of ethoprophos and oxamyl was investigated against the southern root-knot nematode, *M. incognita* on tomato plants in two experiments under greenhouse conditions (Table 1). All of the tested treatments were found to be effective in protecting and improving tomato growth in comparison to the untreated plants.

The most effective treatments against second stage juveniles (J₂) were ethoprophos (granular), abamectin and oxamyl (granular) with reductions by 81.62, 81.07 and 76.38%, respectively. The liquid formulations of both oxamyl and ethoprophos recorded reductions by 72.67 and 66.82%, respectively. The same trend was noticed in the second experiment where ethoprophos (granular), oxamyl (granular) and abamectin were the superior treatments which recorded reductions in J₂ with the same significance by 82.02, 80.86 and 78.88%, consecutively. The liquid formulations of oxamyl and ethoprophos gave the relatively less reduced soil population by 69.73 and 63.86%, respectively.

Based on root galling, both oxamyl and ethoprophos at granular formulation gave reductions by 87.44 and 81.54% with the same significance, respectively. Abamectin, oxamyl and ethoprophos in liquid

formulations minimized the galls by 71.64, 57.90 and 46.82%, respectively. In the second experiment, the granular formulations of oxamyl and ethoprophos were the superior treatments which decreased galls by 86.71 and 83.15%, respectively. Abamectin and the liquid formulations of oxamyl and ethoprophos recorded decreasing by 72.48, 63.00 and 52.16%, respectively.

According to our study, all tested nematicides showed that granular nematicides have highly nematicidal activity against southern root-knot nematode; *Meloidogyne incognita* than liquid formulations based on the detraction in the numbers of second stage juveniles/250g soil and galls / root system. These results are in agreement with certain reports which documented that avermectin "abamectin" have potential against different genera and species of plant parasitic nematodes (El-Tanany *et al.*, 2017; Radwan *et al.*, 2019). Radwan *et al.* (2019) confirmed avermectins such as abamectin and emamectin benzoate were effective against *M. incognita* *in vitro* and *in vivo* on tomato plants. Also, Khalil and Abd El-Naby (2018) reported that abamectin alone or combined with bio-agents significantly decreased galls and J₂ of *M. incognita* on tomato plants.

Saad *et al.* (2017) investigated oxamyl and ethoprophos in granular forms as well as abamectin against *M. incognita* on tomato plants. Results showed that oxamyl, ethoprophos and abamectin diminished galls in tomato roots by 89.53, 83.23 and 66.69%, respectively. In addition, they decreased J₂ in soil by 83.92, 75.90 and 75.34%, respectively. Mostafa *et al.* (2015) reported the tested commercial oxamyl products gave the best results in reducing root knot nematodes on potato plants. On the contrary, in a study, cadusafos as liquid formulation proved superiority in decreasing the incidence of root-knot nematodes infecting cucumber plants than granular one Amin and Abd El-Wanis (2014).

Abamectin is a novel nematicide which belongs to avermectins group to manage plant parasitic nematodes. According to Corbett *et al.* (1984), when *M. incognita* were exposed to 20mM aqueous solution of avermectin B_{2,a} 23 -ketone, they (1) initially lost movement within 10min., (2) partially recovered within 30 min. and (3) irreversibly lost movement after 120 min. Abamectin has a unique mode of action where targeted the δ - amino-butyric acid (GABA) receptors which causing enhancement in the influx chloride ions which finally causing death of nematodes (Martin *et al.*, 2002), and inhibiting egg hatching of root knot nematode, *M.*

incognita (Radwan *et al.*, 2019). Moreover, abamectin is adsorbed tightly to soil particles which attributed to the immobility of abamectin molecules in the soil (Lopez-Perez *et al.*, 2011; Muzhandu *et al.*, 2014).

On the other hand, oxamyl and ethoprophos are belonging to carbamate and organophosphate groups, respectively, and both are considered AChE inhibitors which inhibited acetylcholinesterase in synaptic zones of the nervous system, thereby disrupt nervous transmission at that location (Corbett *et al.*, 1984). Also, non-fumigant nematicides acted against the root-knot nematodes by inhibiting egg hatching, their movement and host invasion by infective juveniles and checking further development of second stage juveniles that had penetrated the roots (Bunt, 1987).

The growth indices of tomato plants such as shoot and root dry weights as affected by the application of abamectin in comparison with two different formulations (granular and liquid) of oxamyl and ethoprophos are presented in Table (2). Data showed that, in untreated plants, *M. incognita* decreased the shoot and root dry weights of tomato plants compared to the treated plants in both experiments under greenhouse conditions.

Abamectin, oxamyl (liquid) and oxamyl (granular) increased the shoot dry weights with the same significance by 107.69, 93.85 and 86.15%, respectively. Ethoprophos in granular and liquid formulations achieved the least increasing over control by 36.92 and 26.15%, respectively. During the second experiment, the same trend was observed with abamectin, ethoprophos (granular), oxamyl (liquid) and oxamyl (granular) which increased the shoot dry weights by 126.44, 109.20, 101.15 and 101.15%, consecutively. However, Ethoprophos (liquid) has-recorded the least increasing (41.38%).

On the other hand, ethoprophos (liquid), abamectin, oxamyl (liquid) significantly enhanced the root dry weights by 91.18, 76.47 and 47.06%, respectively. The granular formulation of ethoprophos and oxamyl showed limited increases by 38.24 and 35.29%, respectively. Furthermore, in the second experiment, results showed that liquid oxamyl was the superior treatment which increased root dry weight (137.50%) followed by granular oxamyl (84.38%). The application of abamectin, as well as ethoprophos at granular and liquid formulations, gave augmentation in root dry weight by 75.00, 68.75 and 31.25%, respectively, without significant differences.

Table 1. The effect of abamectin and two different formulations of ethoprophos and oxamyl on the infection of *Meloidogyne incognita* on tomato plants during two experiments.

Treatments	Formulations	First experiment				Second experiment			
		J ₂ / 250g soil		Galls/ root system		J ₂ / 250g soil		Galls/ root system	
		means	Reduction %	Means	Reduction %	Means	Reduction %	means	Reduction %
Abamectin	2% SC (liquid)	244.80d	81.07	76.80d	71.64	339.00c	78.88	65.00d	72.48
Oxamyl	10% G (granular)	305.40cd	76.38	34.00e	87.44	307.20c	80.86	31.40e	86.71
	24% SL (liquid)	353.40bc	72.67	114.00c	57.90	485.80b	69.73	87.40c	63.00
Ethoprophos	10% G (granular)	237.60d	81.62	50.00e	81.54	288.60c	82.02	39.80e	83.15
	20 % EC (liquid)	429.00b	66.82	144.00b	46.82	580.00b	63.86	113.00b	52.16
Untreated plants	-	1293.00a	-	270.80a	-	1605.00a	-	236.20a	-

-Values are means of 5 replicates.

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

Table 2. Influence of abamectin and two different formulations of ethoprophos and oxamyl on the growth parameters of tomato plants infected with *Meloidogyne incognita* during two experiments

Treatments	Formulations	First experiment				Second experiment			
		Shoot dry weight(g)		Root dry weight(g)		Shoot dry weight(g)		Root dry weight(g)	
		Means	Increase %	Means	Increase %	Means	Increase %	Means	Increase%
Abamectin	2% SC	1.35 a	107.69	0.6ab	76.47	1.97a	126.44	0.56bc	75.00
Oxamyl	10% G	1.21 a	86.15	0.46bc	35.29	1.75a	101.15	0.59b	84.38
	24% SL	1.26a	93.85	0.50ab	47.06	1.75a	101.15	0.76a	137.50
Ethoprophos	10% G	0.89b	36.92	0.47bc	38.24	1.82a	109.20	0.54bc	68.75
	20 % EC	0.82b	26.15	0.65a	91.18	1.23b	41.38	0.42cd	31.25
Untreated plants	-	0.65b	-	0.34c	-	0.87c	-	0.32d	-

-Values are means of 5 replicates.

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

Many investigations were found that abamectin enhanced the tomato plant growth characteristics as shoot and root systems (Saad *et al.*, 2012; Muzhandu *et al.*, 2014; Khalil and Abd El-Naby, 2018). Our findings are also in agreement with the data of Khalil *et al.* (2012) and Saad *et al.* (2017) who found that abamectin when applied against *M. incognita* infecting tomato plants, increased all plant growth parameters. Also, the treated tomato plants with abamectin increased the shoot and root dry weights by 16.92 and 14.26%, respectively (Radwan *et al.*, 2019).

Saad *et al.* (2017) indicated that granular oxamyl increased the tomato shoot dry weight by 90.74%, and root dry weight by 50.00%. However, liquid oxamyl induced increases in the tomato shoot dry weight by 22.28%, and root dry weight by 46.02% (Ibrahim *et al.*, 2018). Such improvement in plant growth is possible due to the reduction in plant parasitic nematode populations which allow plants to grow naturally. Generally, our study showed that granular formulation showed the highest augmentation in plant indices than the liquid formulation, except for ethoprophos in the liquid formulation which gave the greatest enhancement in root dry weight than granular one and this may be due to environmental factors.

CONCLUSION

Finally, we can conclude that abamectin (2% SC) according to our study is successful new nematicide and at par with the granular formulation (10% G) which proved their superiority in suppressing second stage juveniles. However, granular formulation decreased root galls significantly than liquid formulations (2% SC, 20% EC and 24% SL) and this may be attributed to the slow release of active ingredients into the soil. Meanwhile, the relative less effective suppression of liquid formulations may be due to the leaching of nematicides into the lower layers of the soil. Also, abamectin was the greatest treatment among the tested liquid formulation, therefore, abamectin can be used as an alternative to non-fumigant nematicides in programs of integrated nematodes management.

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