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EFFICACY OF SOME GRANULAR NEMATICIDES AGAINST ROOT-KNOT NEMATODE, *MELOIDOGYNE INCOGNITA* ASSOCIATED WITH TOMATO

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Abstract

Five granular nematicides namely, cadusafos, carbofuran, ethoprop, fosthiazate and oxamyl were assessed against the root-knot nematode, *Meloidogyne incognita* on tomato based on numbers of galls and juveniles (J_2) as well as on plant growth characteristics in a glasshouse. The rate of the formulated form of oxamyl, carbofuran or cadusafos was 0.1 g/kg soil, while it was 0.125 g / kg soil for fosthiazate and 0.25 g / kg soil for ethoprop. All nematicides caused reduction in root galls and J_2 in the soil. However, 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. Carbofuran, oxamyl and ethoprop ranked intermediate in descending order by 95.06 % and 94.26 %; 81.99 % and 87.60 %; 78.73 % and 87.88 %, respectively. However, none of the nematicides tested significantly affected shoot length, fresh shoot weight and root length compared to the untreated inoculated control. Except oxamyl, all of these nematicides significantly decreased root fresh weight.

Plant parasitic nematodes cause severe damage to a wide range of economic crops. These nematodes produce an annual loss of over US$ 100 billion to world agriculture and an estimated US$ 500 million are usually spent on nematode control (Keren-Zur *et al.*, 2000). The root-knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood, is one of the most harmful root-knot nematode species, and is considered the predominant and economically important on a range of vegetable crops on lighter soil types in Egypt (Ibrahim *et al.*, 2000).

Nematode control is very difficult and relies heavily on the use of soil fumigants and non-fumigant nematicides. Generally, nematicides are the quickest means among the various control measures for drastic reduction of nematode population in a short time. Use of nematicides for the management of plant parasitic nematode population in soil becomes essential when other methods like cultural practices, resistant varieties and biocontrol agents are unable to protect crops from these pests (Hague & Gowen, 1987). However, several fumigants and nematicides have been withdrawn from the market in the last few decades due to concerns about the environment safety as well as human health (Rich *et al.*, 2004). Currently available soil fumigants, such as dichloropropene and metham-sodium, are less effective than methyl bromide for controlling nematodes, making the role of non-fumigant nematicides more important. On the other hand, granular non-fumigant nematicides are more easily applied and safer for farmers compared with fumigants (Lamberti *et al.*, 2000). The most widely used non-fumigant nematicides are aldicarb, cadusafos, carbofuran, ethoprop, fenamiphos, fosthiazate, oxamyl and terbufos, which are organophosphate or carbamate based nematicides. Nevertheless, nematicides still continue to be a main nematode management approach, whether used as part of an integrated management programme or as the sole control component. Therefore, the objective of the present study was to evaluate the efficacy of some granular nematicides for the management of *M. incognita* infecting tomato plants.

Materials and Methods

Nematicides used: Five granular nematicides viz., cadusafos (Rugby ® 10 % G), carbofuran (Furadan® 10 % G), ethoprop (Mocap® 10 % G), fosthiazate (Nemathorin ® 10 % WG) and oxamyl (Vydate ® 10 % G) were used in the present study. Cadusafos and carbofuran were obtained from FMC Corporation, Agriculture Chemical Group; ethoprop was supplied by Bayer Crop Science France; fosthiazate was obtained from Syngenta and oxamyl was supplied by E. I. du Pont de Nemours & Company Inc.

Nematode inoculum: The root-knot nematode *M. incognita* was isolated from infected roots of eggplant (*Solanum melongena* L.) obtained from El-Nubaria region, Behera Governorate, Egypt. Eggs and second-stage juveniles (J_2) were extracted from infected roots by the sodium hypochlorite method (Hussey & Barker, 1973).

Pot experiment: A pot experiment was conducted to evaluate the efficacy of ethoprop, oxamyl, carbofuran, fosthiazate and cadusafos against *M. incognita* on tomato plants. All clay pots of 12 cm diameter filled with 1 kg of steam sterilized sandy clay loam soil (68 % sand, 6 % silt and 26 % clay, pH 7.8, 0.7 % organic matter). A pair of tomato seedlings (*Solanum lycopersicum* L. cv. Super Strain B) of one month-old were transplanted in each pot and watered every day. The nematicides were applied to the soil at the recommended dosage rate, after 3 days from transplanting time. Oxamyl, carbofuran and cadusafos were added to the soil @ 0.1 g / kg soil, but ethoprop was added @ 0.25 g / kg soil and fosthiazate was added @ 0.125 g / kg soil based on the formulated form. Each pot was inoculated with 5000 nematode eggs after five 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 three times and arranged in a complete randomized block design on a bench in a greenhouse at 27-32 °C and 65-70 % RH. After 50 days from inoculation time, plants were removed from the pots and the roots were washed free of soil. Top and root length and fresh weight, number of galls / root system and number of J_2 / 250 g soil were determined for each of the plants. The second stage juveniles (J_2) were extracted from the soil by the decanting and sieving technique (Goodey, 1963) and counted.

Statistical analysis: Data obtained were statistically analyzed according to SAS software program (SAS Institute, 1998). Data of the numbers of nematode root galls and juveniles were transformed to $\sqrt{x+1}$ before statistical analysis. Comparison among means was made *via* the least significant difference (LSD) at the 5% level of probability.

Results and Discussion

Table 1 showed significant effect for all tested nematicides in reducing the number of galls compared with untreated control. Fosthiazate @ 0.125 g / kg soil was found to be the most effective, since it reduced the number of galls more than those of the other compounds at their doses tested. However, fosthiazate @ 0.125 g / kg soil and carbofuran @ 0.1g / kg soil were at par with percent reduction of 97.52 and 95.06, respectively. On the other hand, cadusafos @ 0.1g / kg soil and ethoprop @ 0.25 g / kg soil were relatively effective treatment, which reduced galls by 77.51 % and 78.73 %, respectively. However, cadusafos did not differ from ethoprop or oxamyl. Oxamyl @ 0.1 g / kg soil was intermediate, as it suppressed galls by 81.99 %.

All tested nematicides were effective at the doses tested (which were not equal) in reducing the number of J_2 in the soil compared to the untreated control. The highest activities were obtained for fosthiazate @ 0.125 g / kg soil (96.45 %) and carbofuran @ 0.1 g / kg soil (94.26 %) whereas the lowest was observed with cadusafos @ 0.1 g / kg soil (86.63 %). Ethoprop @ 0.25 g / kg soil and oxamyl @ 0.1 g / kg soil were ranked intermediate, as they reduced J_2 by 87.88 % and 87.60 %, respectively. No significant differences were observed between fosthiazate and carbofuran as well as among cadusafos, ethoprop and oxamyl in reducing the number of J_2 in the soil at the doses tested (Table 1).

Data in Table 2 showed that, in untreated plants, *M. incognita* reduced plant growth parameters compared to nematode-free plants. All of the tested nematicides did not significantly differ from the untreated inoculated control in their effects on shoot length, shoot fresh weight and root length. All of the tested nematicides, except oxamyl significantly decreased the root fresh weight.

Results on the efficacy of the tested nematicides on *M. incognita* and on the growth on tomato were in conformity with Minton *et al.*, (1993), Lawrence & McLean (1995), Ingham *et al.*, (2000), Giannakou *et al.*, (2005) and Hafez & Sundararaj (2006). These authors reported that fosthiazate provided excellent control of root-knot nematodes and increased plant growth and yield. In addition, cadusafos and fosthiazate reduced *M. arenaria* population on winter-grown oriental melon from 35 to 90 % compared with control (Kim *et al.*, 2002). However, fosthiazate was better than cadusafos and fosthiazate pre-plant plus post-plant application and reduced nematode population densities as much as 90 % and increased yield (Kim *et al.*, 2002). Radwan (1995), Stephan (1995), Badawi & Abu-Gharbieh (2000), Bari *et al.*, (2004), Bhat *et al.*, (2005) and Singh (2006) found that carbofuran gave reduction in the incidence of root-knot nematodes infecting different vegetable crops. In the present investigation, oxamyl followed by ethoprop and cadusafos occupied the second rank in suppressing *M. incognita*. These results are in conformity with Giannakou *et al.*, (2005) who reported that oxamyl provided some nematode control while cadusafos failed to provide adequate nematode control, which may be attributed to the inability of the nematicide to reduce nematode populations even at relatively high concentrations in soil.

Table 1. Effects of some non-fumigant granular nematicides on galls and second stage juveniles (J_2) of *Meloidogyne incognita* infecting tomato in a pot experiment.

Nematicides	Dose (g / kg) (formulated)	Galls (x) / root			Juveniles (x) /250 g soil		
		Numbers	Transformed Data ($\sqrt{x+1}$)	% decrease	Numbers	Transformed Data ($\sqrt{x+1}$)	% decrease
Control (Nematode alone)	-	836	28.91 a	-	770	27.69 a	-
Cadusafos	0.1	188	13.74 b	77.51	103	10.11 b	86.63
Carbofuran	0.1	41	6.50 c	95.06	44	6.60 cd	94.26
Ethoprop	0.25	178	13.35 b	78.73	93	9.63 bc	87.88
Fosthiazate	0.125	21	4.64 c	97.52	27	5.19 d	96.45
Oxamyl	0.1	151	12.19 b	81.99	96	9.69 b	87.60

Each figure is an average of a pair plants for three replicates. Mean in each column followed by the same letter(s) did not significantly differ according to LSD ($p = 0.05$).

Table 2. Influence of some non-fumigant granular nematicides on the growth parameters of tomato plants infected with *Meloidogyne incognita* in a pot experiment.

Treatments	Dose (g/kg) (formulated)	Growth indices			
		Shoot		Root	
		Length (cm)	Weight (g)	Length (cm)	Weight (g)
Control (without nematode)	-	62.25 a	18.56 [a]	26.25 a	6.59 a
Control (with nematode)	-	50.17 ab	12.06 bc	18.50 bc	6.53 a
Cadusafos @ 1 g / kg soil	0.1	47.25 b	10.63 c	18.00 bc	3.79 b
Carbofuran @ 0.1 g / kg soil	0.1	58.75 ab	13.75 bc	15.25 bc	4.15 b
Ethoprop @ 0.25 g / kg soil	0.25	59.25 ab	13.82 b	14.88 c	4.29 b
Fosthiazate @ 0.125 g/kg soil	0.125	55.00 ab	12.62 bc	13.88 c	3.87 b
Oxamyl @ 0.1 g / kg soil	0.1	54.50 ab	15.02 b	20.33 b	4.56 ab

Each figure is an average of a pair plants for three replicates. Mean in each column followed by the same letter (s) did not significantly differ according to LSD ($P = 0.05$).

On the contrary, cadusafos and ethoprophos suppressed *M. javanica* gall formation on tomato and aubergine. Cadusafos was superior in reducing nematode population and increased the yields over ethoprophos (Stephan *et al.*, 1998; Meher *et al.*, 2010). Moreover, ethoprop and oxamyl did not adequately reduce potato tuber infection by *M. chitwoodi* (Ingham *et al.*, 2000).

The data on the efficacy of the nematicides may be compared in relation to the doses used for each nematicide. From the pooled results, it could be concluded that all nematicidal treatments significantly reduced the root galling and 2^{nd} stage *M. incognita* juveniles in the soil due to both a nematicidal effect on the nematodes in soil and to an inhibition of their penetration. However, fosthiazate at 0.125 g / kg soil had the highest nematicidal effect against both root gall formation and juveniles in soil, while cadusafos at 0.1 g / kg soil proved to be the least effective. Finally, the non-fumigant nematicides tested will likely continue to be used until more biologically based management system can be developed.

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