Zagazig J. Agric. Res., Vol. 33 No. (5) 2006 953 - 972

COMPATIBILITY OF THREE ENTOMOPATHOGENIC NEMATODES WITH CERTAIN HERBICIDES AND NEMATICIDES COMMONLY USED IN EGYPT

Salem, A.A., M.E. Mahrous, M.M. El -Maghraby
and R.M. El - Ashry
Plant Protect. Dept., Fac. of Agric., Zagazig Univ., Egypt.

Accepted 6 / 8 / 2006

ABSTRACT: The toxicity of the nematicides carbofuran, fenamiphos and oxamyl as well as the herbicides butachlor, pendimethalin and thiobencarb to infective juveniles (IJs) of the three entomopathogenic nematodes *viz, Heterorhabditis bacteriophora*(HP88 strain), *Steinernema carpocapsae* (All strain) and *S. riobravis*(unknown strain) was assessed under laboratory condition. The interaction of the preceding pesticides and nematodes against the six instar larvae of *Spodoptera littoralis* (Boisd.) was also investigated.

Data indicated that, one day after treatment, the tested pesticides reduced activity of IJs by 22.96 % to 39.26 % depending on the pesticide and nematode species. When exposure time to pesticides was increased beyond 24 hrs juvenile mortality was obviously increased to reach about 50% after the fourth day. Nematicides were effective than herbicides. Among the tested herbicides, pendimethalin was the most toxic one followed by butachlor and thiobencarb, while the respective trend for the nematicides was oxamyl followed by fenamiphos and carbofuran. *H.bacteriophora* was more sensitive to the tested pesticides as compared to *S. carpocapsae* and *S. riobravis* which showed about the same response against the tested pesticides.

The results obtained indicated that the pesticides screened for their compatibility with *H.bacteriophora*, *S. carpocapsae* and *S. riobravis* in controlling six instar larvae of *S. littoralis* showed additive or antagonistic reactions. No evidence of synergy was observed. The additive effect took place for most of the tested treatments, while antagonistic effect was detected in combinations of *H.bacteriophora* with all the tested pesticides except butachlor; *S. carpocapsae* with pendimethalin and *S. riobravis* with oxamyl. Incompatibility in these cases can be managed by choosing an appropriate time intervals between the applications.

Key words: Compatibility, entomopathogenic nematodes, herbicides, nematicides, *Heterorhabditis bacteriophora*, *Steinernema carpocapsae*, *S. riobravis*, antagonistic effect, additive effect.

INTRODUCTION

Environmental concerns associated with chemical pesticides are forcing scientists to search for less toxic pest management methods. Therefore, during the last decade there has been heightened interest in utilizing steinernematid and heterorhabditid nematodes in controlling insect pests. Since more than 90% of insect species spend at least part of their life cycle in soil, they can be candidates for suppression by these nematodes (Akhurst, 1986). It is known that, soil is suitable for these nematodes, as it provides shelters from environmental extremes and offers the potential for establishment and recycling (Kaya, 1990).

Many classes of pesticides are regularly applied in soil during the growing season of a given crop. Therefore, in developing integrated pest management (IPM) strategies involving the use of entomopathogenic nematodes and chemical pesticides, it is important to detect the degree to which nematodes may be affected by the chemical involved (Gordon *et al.*, 1996). In addition , using low impact pesticides or reduced rates of pesticides simultaneously with biological control agents could achieve adequate control through minimizing the adverse effects of pesticides (Mannion *et al* . , 2000).

Infective juveniles of Steinernematidae and Heterorhabditidae were found to be relatively insensitive to many pesticides (Das&Divakar, 1987; Hara & Kaya, 1983; Rovesti *et al.*, 1988and Zimmermann &Cranshow, 1990). In some studies nematode viability was used as the only parameter to assess their compatibility with pesticides. However, other investigators showed that compatibility should be based on nematode pathogenicity to the insect host as well as its ability to tolerate the effect of pesticides (Kaya & Burlando, 1989).

Compatibility of steinernematid and heterorhabditid nematodes with many herbicides and nematicides was studied by many investigators, since these chemicals are considered the most currently pesticides applied in soil. It was found that most compounds did not interact with the respective nematode species (additive effect) whereas other increased nematode efficacy (synergistic effect). On the other hand, some compounds adversely affect nematode ability to control the target insect; antagonistic effect (Rovesti *et al.*, 1988; Rovesti & Deseo, 1990 and 1991; Gaugler & Campbell,1991 and Gordon *et al.*, 1996). In some cases, a given pesticide was nematostatic, but its removal through washing resulted in normal behavior. For instance, when *S. carpocapsae* was exposed to fenamiphos, no effect on survival or infectivity was observed when infective juveniles were washed from the treated sand after 4 days (Kaya & Burlando, 1989).

The objective of the present study is to determine the effect of field recommended rate of certain herbicides or nematicides, commonly used in Egypt, on viability and infectivity of three entomopathogenic nematodes under laboratory condition.

MATERIALS AND METHODS

Nematode Culture

Infective juveniles of *Heterorhabditis bacteriophora* (HP88 strain), *Steinernema carpocapsae* (All strain) and *S. riobravis* (unknown strain) were obtained from Plant Protection Institute, Agriculture Research Center, Dokki, Giza. The nematode species were cultured separately in last instar larvae of the greater wax moth *Galleria mellonella* L. according to the technique of Dutkey *et al.* (1964). After extraction, IJs were stored in distilled water at 12 °C for 1 week before experimentation (Woodring & Kaya, 1988).

Pesticides Used

Three representative herbicides and nematicides were used. The choice of these compounds was made with emphasis to soil pesticides, since entomopathogenic nematodes are naturally located or more likely to be applied in the soil. Commercially available formulations of the tested pesticides were obtained from Central Laboratory of Pesticides, Dokki , Giza. The herbicides used were butachlor (Machete 60%EC), pendimethalin (Stomp 50%EC) and thiobencarb (Saturn 50%EC). They were used at the recommended field rate of 1.5 litre/feddan which equivalent to 0.90, 0.75 and 0.75 ppm, respectively. Nematicides used were carbofuran (Furadan 10%G), fenamiphos (Nemacure 10%G) and oxamyl (Vydate 24%EC). The applied recommended field dose for carbofuran and fenamiphos was 30 kg/feddan(3ppm), while that for oxamyl was 4 litre /feddan (1ppm). Distilled water was used in the control and to dilute the pesticides to the required concentrations. The granulated pesticides were finely ground to facilitate distribution of the active ingredient between soil particles.

Nematode Viability

Five milliliters of each chemical dilution were placed in Petri dishes (5-cm diameter). The IJs were added to the dilution at the rate of 200 nematodes per dish (0.1 ml of the stock nematode suspension). The control treatment consisted of the 200 IJs maintained in distilled water. Each pesticide was replicated three times. All dishes were sealed tightly with Parafilm to avoid vaporization of the solution. The dishes were placed in an incubator at 25±1°C during the holding period; IJs are more survive at this temperature (Dunphy & Webster, 1986). Replicated aliquots, each of 0.5 ml, were pipetted into Hawksely counting slide and examined by the aid of a research microscope at 100X. Numbers of dead larvae were tailed at one, two and four days after application. The infective juveniles showing inactive straight posture or inactive S posture were considered as dead; any other types of movement were scored as alive (Ishibashi & Taki, 1993).

Combining Effect of Entomopathogenic Nematodes and the Tested Pesticides

The interaction between the three used entomopathogenic nematode species was assessed using the six instar larvae of the cotton leafworm *Spodoptera littoralis* (Boisd.),obtained from a laboratory culture. *S. littoralis* was reared on castor leaves. Only appearently healthy larvae were used in this bioassay. Plastic containers measured 9-cm diameter and 4-cm deep were filled with 150 grams of sterilized sandy soil. Forty ml of each pesticide dilution, or distilled water in the case of the control treatment, were added to each container. This volume of the diluent agent was quite enough to moisten the sand soil. The nematodes were allowed to acclimate at room temperature for about 6 hours before application. Two milliliters of nematode suspension were added to the soil surface of each container at the rate of 4000 IJs/container.

Ten six instar larvae of *S. littoralis* were transferred to the soil surface of each container. Treatments of nematode alone, pesticide alone and free from both were considered. Each treatment was replicated 5 times using different batches of nematode strains and *S. littoralis* to insure heterogenesis. All containers were kept in the laboratory at 20±3°C. Three days after application, larval mortality was checked and dead larvae were removed from the containers. Cadavers were examined for signs of nematode infection. Dead larvae were placed individually in the modified White traps (White, 1927) to observe nematode emergence. Few larvae, whose color was not altered nematode infection, were dissected to check the presence of nematodes.

Analysis of the Interaction Data of Mixtures

Interaction data for mixtures were estimated using Limpel's formula reported by Richer (1987) as follows: $E=X+Y-XY/100$

Where:

E=The expected additive effect of the mixture.

X= The effect due to component A alone.

Y= The effect due to component B alone.

The expected effect was compared with the actual effect obtained experimentally for the mixture to determine the additive, synergistic or antagonistic effects according to the equation given by Mansour *et al.*(1966) as follows:

Co- toxicity factor =

$$\frac{\text{Observed effect(\%)} - \text{Expected effect(\%)}}{\text{Expected effect (\%)}} \times 100$$

This factor was used to classify results into three categories. A positive factor 20 or more is considered potentiation, a negative factor 20 or more means antagonism and intermediate values between -20 and +20 indicate only additive effect.

RESULTS AND DISCUSSION

Toxicity of Certain Herbicides to Infective Juveniles of *H.bacteriophora*, *S. carpocapsae* and *S.riobravis*

Data in Table 1 show percent mortality of IJs of *H.bacteriophora* , *S. carpocapsae and S.riobravis* in suspensions of the three herbicides butachlor, pendimethalin and thiobencarb. One day after treatment, mortality percentages in butachlor were 33.10, 25.36 and 24.67 for *H. bacteriophora* , *S. carpocapsae* and *S. riobravis*, respectively with general mean of

Table.1. Percent mortality of infective juveniles of *H.bacteriophora*, *S. carpocapsae* and *S.riobravis* as influenced by certain herbicides at 1, 2 and 4 days after treatment

Herbicides	Trade name/ Formulation	Days after treatment	Nematode species			General mean
			H.bacteriophora	*S. carpocapsae*	*S.riobravis*	
Butachlor	Machete (60% EC)	1	33.10 B	25.36 A	24.67 A	27.71 a
		2	45.10 B	38.76 A	36.46 A	40.10 b
		4	58.12 C	49.60 B	46.10 A	51.27 c
Pendimethalin	Stomp (50%EC)	1	39.26 C	28.13 B	25.30 A	30.89 a
		2	48.40 B	40.43 B	37.36 A	42.06 b
		4	59.76 B	53.03 A	48.26 A	53.68 c
Thiobencarb	Saturn (50% EC)	1	31.18 B	24.16 A	22.96 A	26.10 a
		2	43.66 B	37.03 A	35.16 A	38.61 b
		4	57.88 B	47.73 A	45.26 A	50.29 c

*** Dosage rate for the tested herbicides was 4 L./fed.**

*** The same lowercase letter in columns or uppercase letter in rows indicate no significant differences at P = 0.05 according to Duncan's multiple range test.**

27.71%. Whereas, the parallel values in pendimethalin and thiobencarb at the same period were 39.26(31.18), 28.13(24.16) and 25.30(22.96) % with general means of 30.89(26.10)%, respectively. On the other hand, two days after treatment, general mean of percent mortality for the three nematode species was significantly increased to 40.10, 42.06 and 38.61% with butachlor, pendimethalin and thiobencarb, respectively. However, after the fourth day the the tested herbicides killed more than 50% of IJs, with significantly increased values of 51.27, 53.68 and 50.29 % for butachlor, pendimethalin and thiobencarb, respectively. Generally, IJs of *H. bacteriophora*, however, were more sensitive to the tested compounds as compared to *S. carpocapsae* and *S. riobravis*(Fig.1). The two species, *S. carpocapsae* and *S. riobravis*, however, showed similar susceptibility to each of butachlor and thiobencarb with insignificant varaition. Mortality percentages, in *S. carpocapsae* and *S. riobravis* one and two days after treatment were significantly different when IJs were expose to pendimethalin. It means that the effect of this compound significantly varied with nematode species.

Statistical analysis showed that thiobencarb was significantly less toxic against the three nematode species as compared to butachlor and pendimethalin where insignificant difference took place. General means of mortality percentages for the tested herbicides on the three nematode species after one day of treatment could be ascendingly arranged as follows: 30.89,27.71and 26.10 with pendimethalin, butachlor and thiobencarb, respectively (Fig.2). The corresponding figures, after two days were 42.06, 40.10 and 38.61. These figures, however, reflect the slight species specificity of the three tested herbicides.

Toxicity of Certain Nematicides Against Infective Juveniles of *H.bacteriophora*,*S. carpocapsae* and *S.riobravis*

Data in Table 2 illustrate percent mortality of *H.bacteriophora*, *S. carpocapsae* and *S.riobravis* as influenced by the nematicides carbofuran, fenamiphos and oxamyl used at the recommended field dose. One day after exposure, percent mortality of *H.bacteriophora* in aqueous solutions of carbofuran , fenamiphos and oxamyl were 33.16, 36.33 and 38.11%, respectively.These values for *S. carpocapsae* and *S. riobravis* were

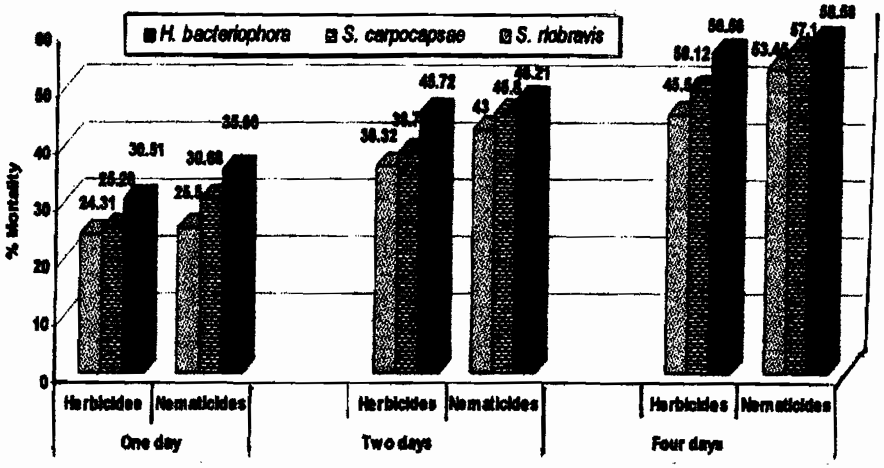

Fig. 1 . General mean of IJs percent mortality for *H. bacteriophora, S. carpocapsae and S. riobravis* as influenced by the tested herbicides and nematicides at 1,2 and 4 days after treatment.

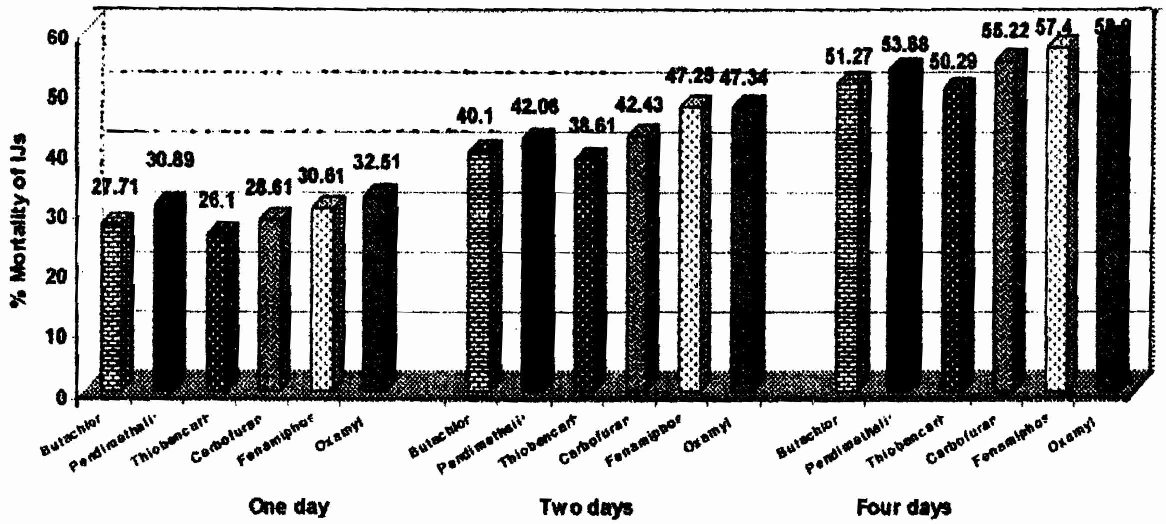

Fig. 2. General mean of IJs percent mortality for butachlor, pendimethalin and thiobencarb(herbicides) and carbofuran, fenamiphos and oxamyl (nematicides) at 1, 2 and 4 days after treatment.

Table2. Percent mortality of infective juveniles of *H.bacteriophora* , *S. carpocapsae* and *S.riobravis* as influenced by certain nematicides at 1, 2 and 4 days after treatment

Nematicides	**Trade name/ Formulation**	**Days after treatment**	**Nematode species**			**General mean**
			H.bacteriophora	***S. carpocapsae***	***S.riobravis***	
Carbofuran	**Furadan (10% G)**	**1**	**33,16 C**	**29.66 B**	**23,03 A**	**28.61 a**
		2	**45.16 B**	**42.06 A**	**40.09 A**	**42.43 b**
		4	**57.96 B**	**56.06 B**	**51.66 A**	**55.22 c**
Fenamiphos	**Nemacure (10% G)**	**1**	**36.33 C**	**30.61 B**	**24.91 A**	**30.61 a**
		2	**49.56 B**	**48.26 B**	**43.93 A**	**47.25 b**
		4	**60.00 B**	**59.10 B**	**53.10 A**	**57.40 c**
Oxamyl	**Vydate (24%L)**	**1**	**38.11 C**	**31.77 B**	**27.67 A**	**32.51 a**
		2	**49.93 B**	**47.10 A**	**45.00 A**	**47.34 b**
		4	**62.00 B**	**59.10 A**	**55.60 A**	**58.90 c**

*** Dosage rate for carbofuran and fenamiphos was 30kg./ fed., while for oxamyl was 4 L./fed.**

*** The same lowercase letter in columns or uppercase letter in rows indicate no significant differences at P = 0.05 according to Duncan's multiple range test.**

29.66(23.03), 30.61(24.91) and 31.77(27.67) %, respectively. Oxamyl gave the highest effect followed by fenamiphos while carbofuran showed the lowest effective one with general mean of 32.51, 30.61 and 28.61%, respectively. Likewise, similar trend was obtained, when exposure time was increased to 2 days.General mean for the three nematode species was significantly increased to 47.34, 47.25 and 42.43%, respectively. However, after the fourth day a relatively higher numbers of juveniles were killed indicating the same trend with general mean values of 58.90, 57.40 and 55.22%, respectively. On the other hand, statistical analysis show that insignificant varaitions were detected between fenamiphos and oxamyl as compared to carbofuran which significantly gave the lowest general mean of percent mortality at the three time intervals. Significant differences existed in level of tolerance between the three nematode species against the tested nematicides. Generally, it could be concluded that, *H. bacteriophora* is more sensitive to the tested nematicides followed by *S. carpocapsae* and *S. riobravis*. It is necessary to mention here that the nematicides are more toxic to IJs of heterorhabditid and steinernematid nematodes as compared to the tested herbicides which were less toxic(Fig.2).

Nematodes and Herbicides Combinations

Data in Table 3 show mortality response of integrating the herbicides butachlor, pendimethalin and thiobencarb with the entomopathogenic nematode species, *H. bacteriophora* , *S. carpocapsae* and *S. riobravis* on six instar larvae of *S. littoralis*. It was found that, an additive effect took place when the recommended rate of butachlor was combined with each of the three tested species; C.F. values with *H. bacteriophora* , *S. carpocapsae* and *S. riobravis* were -0.33, -14.10 and 0.52, respectively. However, when pendimethalin was tested with the nematode species, antagonistic effect occurred with *H. bacteriophora* and *S. carpocapsae* with C.F. values of -27.57 and -22.57, respectively. *S. riobravis*/ pendimethalin combination gave additive effect with C.F. value of -4.97. On the other hand, antagonism was noticed with combination of thiobencarb and *H. bacteriophora* gaining C.F. value of -20.12, while the same herbicide showed additive effect with *S. carpocapsae* and *S. riobravis* with

Table 3.Mortality response of 6th instar larvae of *S. littoralis* to recommended rate of certain herbicides and entomopathogenic nematode species

Herbicides	Trade name/ Formulation	Nematode Species	%Mortality (Nematodes+ Herbicides)		Co-toxicity factor (C.F.)	Response
			Observed	Expected		
Butachlor	Machete 60% EC	*H.bacteriophora*	59.40	59.60	-0.33	additive
		S. carpocapsae	56.80	66.12	-14.10	additive
		S.riobravis	69.40	69.03	0.52	additive
Pendimethalin	Stomp 50%EC	*H.bacteriophora*	43.20	59.60	-27.57	antagonism
		S. carpocapsae	51.20	66.12	-22.57	antagonism
		S.riobravis	65.60	69.03	-4.97	additive
Thiobencarb	Saturn 50% EC	*H.bacteriophora*	44.40	55.58	-20.12	antagonism
		S. carpocapsae	54.10	62.75	-13.78	additive
		S.riobravis	63.90	65.95	-3.11	additive

C.F. values of -13.78 and -3.11, respectively. It could be concluded that nematodes / herbicides combinations showed additive or antagonistic effects that depended on the bioactivity of the used herbicide and the susceptibility of the nematode species.

Nematodes and Nematicides Combinations

The mortality response of combining the nematicides carbofuran, fenamiphos and oxamyl with *H. bacteriophora* , *S. carpocapsae* and *S. riobravis* using co-toxicity factor bioassay showed either additive or antagonistic effect when the recommended rate of each nematicide was applied simultaneously with the nematode species (Table 4). Combinations of *H. bacteriophora* with carbofuran, fenamiphos and oxamyl displayed an antagonistic effect on 6th instar larvae of *S. littoralis* with negative C.F. values of 33.16, 21.75 and 23.31, respectively. On contrary, when *S. carpocapsae* was applied with each of the three nematicides, an additive effect was obtained. The response was about to be similar to carbofuran and fenamiphos with values -3.45 and -4.85,while it was, however, different with oxamyl; reaching -19.27. Similarly, the combinations of *S. riobravis* with each of carbofuran and fenamiphos showed additive effect with values of -1.01 and -9.67, respectively. However, the effect of oxamyl was antagonistic with -29.68 C.F. value.

This paper reports the effects of certain herbicides and nematicides on viability and infectivity of *H. bacteriophora* , *S. carpocapsae* and *S. riobravis.* Interaction of carbofuran, fenamiphos and oxamyl with heterorhabditid and steinernematid nematodes was extensively studied. It was found that these compounds are toxic and incompatible with entomopathogenic nematodes. For instance, the organphosphorous nematicide, fenamiphos was the most toxic compound to *S. carpocapsae*. Hara and Kaya (1982) found that this organphosphorus nematicide inhibited reproduction and development of the same nematode species when it was applied at 5 to 10 ppm which equal to field application rates. The same authors (1983) showed that IJs of *S. feltiae* were affected by fenamiphos and oxamyl. Carbofuran and fenamiphos were also found to be toxic to IJs of *H. bacteriophora* and *S. carpocapsae* at the recommended application rates (Rovesti *et al.*, 1988 and Rovesti & Deseo, 1990). Placement of *S. feltiae* and *Galleria* on the sand

Table 4. Mortality response of 6th instar larvae of *S. littoralis* to recommended rate of certain nematicides and entomopathogenic nematode species

Nematicides	Trade name/ Formulation	Nematode Species	%Mortality (Nematodes+ Nematicides)		Co-toxicity factor (C.F.)	Response
			Observed	Expected		
Carbofuran	Furadan 10% G	*H. bacteriophora*	33.80	50.57	-33.16	antagonism
		S. carpocapsae	56.20	58.21	-3.45	additive
		S. riobravis	62.60	63.24	-1.01	additive
Fenamiphos	Nemacure 10% G	*H. bacteriophora*	42.60	54.19	-21.75	antagonism
		S. carpocapsae	58.60	61.58	-4.85	additive
		S. riobravis	59.80	66.20	-9.67	additive
Oxamyl	Vydate 24%L	*H. bacteriophora*	40.60	52.94	-23.31	antagonism
		S. carpocapsae	48.60	60.54	-19.72	additive
		S. riobravis	46.80	65.28	-29.68	antagonism

surface at the same time with fenamiphos granules totally suppressed activity of the nematodes. The presence of fenamiphos on sand adversely affected the ability of *S. feltiae* to infect an insect host. Fenamiphos was nematostatic in sand over 4-7 day exposure period, but nematodes were infectious when they were extracted from sand (Kaya& Burlando, 1989). Oxamyl and fenamiphos reduced infectivity of *S. feltiae* and *S. carpocapsae* against larvae of *G. mellonella* in sand-tube bioassay when compared with controls (Patel& Wright, 1996).

In contrast, some reports revealed that oxamyl increased efficacy of entomopathogenic nematodes. Ishibashi (1993) showed that oxamyl increased *S. carpocapsae* efficiency against *Agrotis segatum* synergistically, but only in fumigated soil, probably by enhancing the nematode nictating behavior. Nishimatsu& Jackson (1998) showed that effective field results was obtained when many insecticides, including oxamyl, were simultaneously used with nematodes compared to application of nematodes or insecticides alone. Regarding herbicides, Rovesti *et al.* (1988) tested the effect of 25 herbicides on IJs of *H. bacteriophora* . They indicated that herbicides had generally little effect on IJs. Alachlor was the most toxic compound. However, the nematodes recovered after washing or placing in sand. Trifluralin and pendimethalin had a strong effect on the IJs vitality, but had no effect on infectivity and mobility. Likewise, Rovesti & Deseo(1990) revealed that most herbicides and fungicides were not toxic to *S. carpocapsae* and *S. feltiae,* while a high proportion of insecticides , acaricides and nematicides induced adverse effects ranging from impaired movement and infectivity to death of IJs.

The increased efficacy of pesticide-nematode combinations was attributed to the effect on the insect rather than on the nematode. The paralytic and convulsive response of the insect to the insecticide renders the insect more susceptible to nematode infection. Also, increased metabolic activity and reduced directional movement increased the localized production of CO2 which is used by nematode for host finding (Gaugler *et al.* 1980 and Nishimatsu& Jackson, 1998). showed that effective field results was obtained when many insecticides, including oxamyl, were simultaneously used with nematodes compared to application of nematodes or insecticides alone.

Regarding herbicides, Rovesti *et al.* (1988) tested the effect of 25 herbicides on IJs of *H. bacteriophora* . They indicated that herbicides had generally little effect on IJs. Alachlor was the most toxic compound. However, the nematodes recovered after washing or placing in sand. Trifluralin and pendimethalin had a strong effect on the IJs vitality, but had no effect on infectivity and mobility. Likewise, Rovesti & Deseo(1990) revealed that most herbicides and fungicides were not toxic to *S. carpocapsae* and *S. feltiae*, while a high proportion of insecticides , acaricides and nematicides induced adverse effects ranging from impaired movement and infectivity to death of IJs.

The increased efficacy of pesticide-nematode combinations was attributed to the effect on the insect rather than on the nematode. The paralytic and convulsive response of the insect to the insecticide renders the insect more susceptible to nematode infection. Also, increased metabolic activity and reduced directional movement increased the localized production of CO2 which is used by nematode for host finding (Gaugler *et al.* 1980 and Nishimatsu& Jackson, 1998).

Our results are in accordance with those obtained by other investigators, who indicated that *H. bacteriophora* spp. were more sensitive to pesticides as compared to *Steinernema* spp.(Rovesti *et al.*, 1988; Siriusingh *et al.*,1991 and Koppenhofer *et al.*, 2000). However, Rovesti& Deseo(1990) reported that the response of *Steinernema* species to different pesticides appeared to be very similar.

Generally, implementation of heterorhabditid and steinernematid nematodes is one of the most promising choices to minimize usage of chemical pesticides. From the present study, it would be appear that simultaneous usage of the tested herbicides and nematicides with entomopathogenic nematodes, especially *Heterorhabditis* spp., in IPM may require applying the chemical and biological control agents in sequence, separated by time intervals that would be sufficient to minimize the toxicity effects on the nematodes.

REFERENCES

Akhurst, R. J. 1986. Controlling insects with entomopathogenic nematodes. *In* : Fundamental Applied Aspects of Invertebrate Pathology. Eds.: Samson, R. A., Valk, J. M.,and Peter, P. Proc. 4th Int. Coll. Inverteb. Pathol., 265 pp.

Das, J. N. and B. J.Divakar.1987. Compatibility of certain pesticides with DD-136 nematodes. Plant Protection Bulletin , India 39(1-2):20-22.

Dunphy, G. and J. M. Webster. 1986. Temprature effects on the growth and virulence of *Steinernema feltiae* strains and *Heterorhabditis heliothidis* . J. Nematol. , 18:270-272.

Dutkey , S. R. , J. V. Thompson and G.E. Cantwell. 1964. A technique for the mass propagation of the DD-136 nematode. Journal of Insect Pathology , 6: 417- 422.

Gaugler, R., L. Le Back, B. Nakagaki and G. M. Boush. 1980. Orientation of the entomogenous nematode, *Neoaplectana carpocapsae* , to carbon dioxide. Environmental Entomology, 8, 658.

Gaugler, R. and J. F.Campbell. 1991. Behavioral response of the entomopathogenic nematodes *Steinernema carpocapsae* and *Heterorhabditis bacterophora* to oxamyl . Annal of Applied Biology, 119(1):131-138.

Gordon, R., J. Chippett and J. Tilley. 1996. Effect of two carbametes on infective juveniles of *Steinernema carpocapsae* All strain and *Steinernema feltiae* Umea strain. J. Nematol. , 28(3):310-317.

Hara ,A. H. and H.K. Kaya. 1982. Effects of selected insecticides and nematicides on the *in vitro* development of the entomogenous nematode , *Neoaplectana carpocapsae* . J. Nematol., 14(4):486-491.

Hara, A. H. and H.K. Kaya. 1983. Toxicity of selected organophosphate and carbamate pesticides to infective juveniles of the entomogenous nematode *Neoaplectana carpocapsae* (Rhabditida :Steinernematidae). Envirnomental Entomology, 12(2):496-501.

Ishibashi , N. 1993. Integrated control of insect pests by *Steinernema carpocapsae. In*: Nematodes as Biological Control of Insects. Eds: Bedding, R.; Akhurst and Kaya, H. K. , pp. 105-113. CSIRO , East Melbourne.

Ishibashi , N. and S. Takii. 1993. Effect of insecticides on movement, nictation and infectivity of *Steinernema carpocapsae* J. Nematol., 25(2):204-213.

Kaya , H. K. 1990. Soil ecology. *In*: Entomopathogenic Nematodes in Biological Control Eds.: Gaugler, R. and Kaya,H. K., pp. 93-116. CRC Press, Boca Raton,Florida .

Kaya , H. K. and T. M. Burlando. 1989. Infectivity of *Steinernema feltiae* in fenamiphos –treated sand . J. Nematol . ,21:434-436.

Koppenhofer ,A. M., I. M. Brown , R. Gaugler , P. S. Grewal , H. K. Kaya and M.G. Klein. 2000. Synergism of entomopathogenic nematodes and imidacloprid against white grups:greenhouse and field evaluation. Biological Control, 19(3):245-251.

Mannion ,C. M. , H. E. Winkler, D. I., Shapiro and T. Gibb 2000. Interaction between halofenozide and the entomopathogenic nematode *Heterorhabditis maretalus* for control of Japanese bettle (Coleoptera : Scarabaeidae) larvae. Journal of Economic Entomology , 93(1):48-53.

Mansour, N. A., M.E. EL-Dafrawi, A. Tappozada and M. I. Zeid. 1966 Toxicological studies on the Egyptian cotton leafworm, *Prodenia litura* . VI. Potentiation and antagonism of organophosphorous and carbamate insecticides. Journal of Economic Entomology, 59:307-311.

Nishimatsu , T. and I. J. Jackson. 1998. Interaction of insecticides , entomopathogenic nematodes , and larvae of the western corn rootworm (Coleoptera: Chrysomalidae). Journal of Economic Entomology , 91(2):410-418.

Patel, M. N. and D.J. Wright. 1996. The influence of neuroactive pesticides on the behaviour of entomopathogenic nematodes . Journal of Heleminthology , 70(1):53-61.

Richer. D. L. 1987. Synergism – a patent view . Pestic. Sci., 19:309-315.

Rovesti, L.and K. V. Deseo. 1990. Compatibility of chemical pesticides with entomopathogenic nematodes, *Steinernema. carpocapsae* Weiser and *S. feltiae* Filipjev (Nematoda: Steinernematidae). Nematologica , 36(2):237-245.

Rovesti, L.and K. V. Deseo. 1991. Compatibility of pesticides with entomopathogenic nematode, *Heterorhabditis heliothidis.* Ibid. 37(1):113-116.

Rovesti, L., E. W. Heinzpeter, F. Tagliente and K. V. Deseo 1988. Compatibility of pesticides with entomopathogenic nematode *Heterorhabditis bacteriophora* Poinar (Nematoda: Heterorhabditidae). Ibid. 34(4):462-476.

Sirjusingh, C., H. Mauleon, A.Kermarrec, C. Pavis, and A. Kermarrec, 1991. Compatibility and synergism between entomopathogenic nematodes and pesticides for control of *Cosmopolites sordidus* Germar. Rencontres caraibes en lutte biologiqu. 1991, 183-192; In Proceeding of the Caribbean meetings on biological control, Guadeloupe, 5-7 November 1990.

White, G. F. 1927. A method for obtaining infective nematode larvae from cultures. Science , 66 : 302-303.

Woodring, J. L. and H. K. Kaya 1988. Steinernematid and heterorhabditid nematodes : A handbok of techniques. Southern Cooperative Series Bulletin 331. Arkansas Agricultural Experiment Station. Fayetteville, Arkansas,30 pp.

Zimmerman,R. J.and W. S.Cranshow. 1990 . Compatibility of three entomopathogenic nematodes (Rhabditida) in aqueous solutions of pesticides used in turfgrass maintenance. Journal of Economic Entomology, 83 :97-100.

توافق ثلاثة أنواع من النيماتودا الممرضة للحشرات مع بعض مبيدات الحشائش والمبيدات النيماتودية شائعة الإستخدام فى مصر

أحمد عبد المجيد سالم - مصطفى النبوى محروس
محمد مصطفى المغربى - رمضان محمد العشرى
قسم وقاية النبات - كلية الزراعة - جامعة الزقازيق

قيمت سمية ثلاث من المبيدات النيماتودية (الكاربوفيوران، الفيناميفوس و الاكساميل) وكذلك ثلاث من مبيدات الحشائش(البيتاكلور، البندميثالين ، الثيوبنكارب) بالمعدلات الموصى بها حقليا لثلاثة أنواع من النيماتودا الممرضة للحشرات هى *Heterorhabditis bacteriophora* و *Steinernema carpocapsae* و *S. riobravis* . قيم كذلك تأثير خلط مبيدات الآفات سابقة الذكر على كفاءة أنواع النيماتودا الثلاثة فى إصابة العمر اليرقى السادس لدودة ورق القطن و أجريت التجارب تحت الظروف المعملية.

أوضحت النتائج أنه بعد يوم واحد من المعاملة خفضت المبيدات المستعملة نشاط يرقات النيماتودا المعديةحيث تراوحت نسب الموت ما بين٢٢٠٩٦ %إلى٣٩,٢٦% إعتمادا على نوع المبيد ونوعِ النيماتودا ، و عندما زاد وقت التعرّضِ إلى ما بعد ٢٤ ساعة لزدادت نسبة موت اليرقات المعدية بصورة واضحة لتصل إلى أكثر من ٥٠ % بعد اليوم الرابع. وكانت المبيدات النيماتودية أكثر تأثيرا من مبيدات الحشائش، من بين مبيدات الحشائش كانَ مبيد البندميثالين هو الأكثر سميةِ يليه مبيدَ البيتاكلور ثم الثيوبنكارب ، و بالنسبة للمبيدات النيماتودية كان مبيد الاوكساميل هو الأكثر سمية يليه الفيناميفوس ثم الكاربوفيوران و مِن ناحية أخرى اتضح أن نوع النيماتودا *H. bacteriophora* أكثرَ حسّاسية للمبيدات مقارنة بالنوعين *S. carpocapsae* و *S. riobravis* .

أشارت النتائج المتحَصل عليها والخاصة بتوافق هذه المبيداتَ مع الثلاثة أنواع من النيماتودا الممرضة للحشرات فى مكافحة العمر اليرقى السادس لدودة ورق القطن الى حدوث تأثير اضافة أو تأثير تضاد وظهر تأثير الإضافَة فى أغلب المعاملات المختبرة بينما ظهر تأثير التضاد عند استخدام النوع *H.bacteriophora* مَع كل المبيدات المختبرة ماعدا مبيد البيتاكلور و النوع *S. carpocapsae* مع البند ميثالين و النوع *S. riobravis* مع الاوكسامیل وعموما يمكن التغلب على حالات عدم التوافق هذه بإختيارالفترات الزمنية المناسبة بين المعاملات .