Zagazig J. Agric. Res., Vol. 45 No. (3) 2018 905-916

Plant Protection and Pathology Research

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

COMPATIBILITY OF ENTOMOPATHOGENIC NEMATODES, *Heterorhabditis bacteriophora* Poimar AND *Steinernema carpocapsae* Weiser WITH SOME CHEMICAL AND BIOPESTICIDES

Ramadan M. El-Ashry and A.M. El-Marzoky*

Plant Prot. Dept., Fac. Agric., Zagazig Univ., Egypt

Received: 07/02/2018 ; Accepted: 05/04/2018

ABSTRACT: Effect of the nematicides (abamectin, fenamiphos and oxamyl) as well as the biopesticides (Bio-arc, Bio-zeid and Nemex) on viability and infectivity of infective juveniles (IJs) of the two entomopathogenic nematodes (EPNs) *viz*., *Heterorhabditis bacteriophora* (HP88 strain) and *Steinernema carpocapsae* (All strains) were assessed under laboratory conditions against the six instar larvae of *Galleria mellonella* L. Results indicated that one day after treatment, the tested pesticides reduced the viability of IJs by 9.83 to 23.00% depending on the pesticide and nematode species. After two days, IJs mortality was obviously increased to reach 23.00, 37.50 and 38.33% with the chemical pesticides abamectin, fenamiphos and oxamyl, respectively at the recommended doses. At half recommended doses, IJs mortality reached 14.50, 20.16 and 29.00%, respectively for the same pesticides. Whereas, the parallel values in abamectin, fenamiphos, and oxamyl at the seventh day were 42.83, 63.16; 74.17, 91.83 and 74.00, 86.16% at the half and recommended dose, respectively, after the seventh day, fenamiphos was the most toxic among the tested chemical pesticides followed by oxamyl and abamectin.The biopesticides Bio-arc (*Bacillus megaterium*), Bio-zeid (*Trichoderma album*) and Nemex (*Serratia marcescens*) on IJs mortality of *H. bacteriophora* and *S. carpocapsae* were less toxic as compared to chemical pesticide. After seven days of treatment, at the recommended and half recommended doses, IJs mortality reached to 63.00, 43.66; 45.49, 41.66 and 42.83, 34.17% with Nemex, Bio-arc and Bio-zeid, respectively. Nemex was the most toxic among the tested biopesticides followed by Bio-arc and Bio-zeid. Results indicated that the pesticides screened for their compatibility with *H. bacteriophora* and *S. carpocapsae* in controlling the 6th instar larvae of *G. mellonella* showed an additive or antagonistic reactions. No evidence of synergy was observed. The additive effect took place for most of the tested treatments, while the antagonistic effect was detected in combinations of *H. bacteriophora* with oxamyl, *S. carpocapsae* with fenamiphos and both of *S. carpocapsae* and *H. bacteriophora* with Nemex. Incompatibility in these cases can be managed by choosing an appropriate time-intervals between nematode and pesticide applications.

Key words: Compatibility, entomopathogenic nematodes (EPNs), nematicides, biopesticides, *Heterorhabditis bacteriophora*, *Steinernema carpocapsae*, antagonistic effect, additive effect.

INTRODUCTION

The using of chemical pesticides against insects had been monitored during the recent years for its safety and efficacy, this reason forced scientists to search for less toxic pest management methods. Therefore, during the last 3 decades, there has been heightened interest in utilizing entomopathogenic nematodes EPNs (Steinernematid and Heterorhabditid) and their symbiotically associated bacteria (*Xenorhabdus* spp. For steinernematids and *Photorhabdus* spp. for heterorhabditids) in controlling insect pests. Since more than 90% of insect species spend at least part of their life cycle in the soil, they can be candidated for suppression by the non-feeding, free-living, infective third stage

* **Corresponding author: Tel. :** +201228536236
E-mail address: amr_elmarzoki@yahoo.com

juvenile nematodes occurring in the soil environment (**Akhurst, 1986**). It is known that soil is suitable for these nematodes, as it provides shelter from environmental extremes and offers the potential for establishment and recycling (**Kaya, 1990**).

Poor storage and post-application survival are major obstacles to the expanded use of IJs as bioinsecticides. The nematode formulations had a short shelf-life about 2-years compared to standard chemical pesticides. So, nematodes may be combined with other control agents to achieve better control of a single pest, through additive or, preferably, synergistic effects on pest mortality and 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 biocontrol agents could achieve adequate control through minimizing the adverse effects of pesticides (**Mannion *et al*., 2000**).

Compatibility of steinernematid and heterorhabditid nematodes with many insecticides and nematicides was studied by many investigators since these chemicals are considered the most current pesticides applied in the 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 and Deseo, 1990 and 1991; Gaugler and Campbell, 1991; Gordon *et al.*, 1996**), especially, in some chemicals used as inert ingredients or adjuvants in formulations which can be toxic to nematodes (**Krishnayya and Grewal, 200**2), compatibility of each formulation with the specific nematode species should be evaluated. In some cases, a given pesticide was nematostatic, but it returns to the normal behavior after wash out. 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 and Burlando, 1989**).

Our focus in this paper is to determine the effect of the field recommended rate of certain pesticides, commonly used in Egypt, on viability and infectivity of two entomopathogenic nematodes under laboratory conditions.

MATERIALS AND METHODS

Nematode Culture

Infective juveniles of *Heterorhabditis bacteriophora* (HP88 strain) and *Steinernema carpocapsae* (All strains) were friendly obtained from Department of Entomology and Nematology, University of Florida, USA by Dr. Fahiem Elborai. The nematode species were cultured separately in last instar larvae of the greater wax moth *Galleria mellonella* according to the technique of **Dutkey *et al.* (1964)** and after extraction, IJs were stored in distilled water at 12°C for 1 week until applied in experimentation (**Woodring and Kaya, 1988**).

Greater Wax Moth (*Galleria mellonella*)

The greater wax moth larvae of *G. mellonella* were used to produce progeny of nematode species. Naturally infested combs with *G. mellonella* were obtained from honey hives in Zagazig University. The collected larvae were reared using an artificial medium (**Ekmen *et al*., 2010**). Each jar was provided with a tissue paper as a physical surface for the moths to lay their eggs. The egg masses were transferred frequently to new glass jars containing the nutrient medium. Enough quantity of *G. mellonella* larvae were collected by repeating this technique. After 5-6 weeks, larvae were reached the last instar and collected to be used for nematode propagation.

Pesticides Used

Three representative chemical pesticides and three biopesticides were used. The choice of these compounds was made with an emphasis on soil. Commercially available formulations of the tested pesticides were obtained from Central Laboratory of Pesticides, Dokki, Giza, Egypt. The chemical pesticides used were Laguna 40% EC (fenamiphos), Nemastop 5% CS (abamectin) and Fydal 24% SL (oxamyl). They were used at the recommended field rate of 6, 3 and 5 liters / faddan which equivalent to 6, 3 and 5 ppm,

respectively. Biopesticides used were Bio-zeid 2.5% WP (*Trichoderma album*), Bio-arc 6% WP (*Bacillus megaterium*) and Nemex 2% SL (*Serratia marcescens*). The applied recommended field dose for Bio-zeid and Bio-arc was 40 kg/faddan (40 ppm), while that for Nemex was 4 liters/faddan (4 ppm), half of these recommended doses were also used to realize the effect of optimum dose on IJs bioavailability. Distilled water was used in the control and to dilute the pesticides to the required concentrations.

Nematode Viability

Five milliliters of each chemical dilution were poured in Petri dishes (5-cm diameter). The IJs were added to the dilution at the rate of 100 nematodes per dish (0.1 ml of the stock nematode suspension). The control treatment consisted of the 100 IJs maintained in distilled water. Each pesticide was replicated three times. All dishes were sealed tightly with parafilm to avoid vaporization of the solution. Dishes were placed in an incubator at 25±1°C during the holding period. IJs survive more at this temperature (**Dunphy and Webster, 1986**). Each of 0.5 ml, were pipetted into a Hawksely counting slide and examined by the aid of a research microscope at 100x. Numbers of dead individuals were observed 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 and Takii, 1993**) or did not show any movement after prodding were considered dead (**Elizabeth *et al.*, 2003**). Percent of dead nematodes was calculated by the following equation: Percent of dead IJs (PD%) = total number of nematode individuals - number of dead nematodes ÷ total number of nematode indiviuals × 100

Combining Effect of Entomopathogenic Nematodes and Tested Pesticides

The interaction between the two used entomopathogenic nematode species was assessed using the 6th instar larvae of *G. mellonella*. Apparently 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 sandy 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 6th moth larvae of *G. mellonella* were placed on the surface of each plastic 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 *G. mellonella* to ensure heterogenesis. All containers were kept in the laboratory at 21±3°C. The pots were sealed with a perforated upper lid to prevent insects from escaping.

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 form 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 = The observed effect (%) – Expected effect (%) ÷ Expected effect (%) × 100

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

Statistical Analysis

The experiments were carried out in a completely randomized design with 3 replications for each treatment. Data were subjected to analysis of variance (ANOVA) using **MSTAT VERSION 4 (1987)**. Means were compared by Duncan's multiple range test at $P < 0.05$ probability.

RESULTS AND DISCUSSION

Toxicity of Certain Nematicides to Infective Juveniles of *S. carpocapsae* and *H. bacteriophora.*

Results in Table 1 show that one day after treatment, mortality percentages in fenamiphos treatment were 16.67 and 12.00 for, *S. carpocapsae* and *H. bacteriophora*, respectively at half recommended dose with a general mean of 14.33. Whereas, the parallel values in abamectin and oxamyl at the same period were 12.33, 7.33 and 22.67, 17.67 for the same nematode species while, the general means were 9.83, 20.17, respectively. In the recommended dose, mortality percentages of the two EPNs increased to reach 25.33, 20.67 in fenamiphos and in the same trend to 16.67, 11.00 and 25.33, 20.67 in abamectin and oxamyl treatments, respectively after one day of treatment.

However, at half recommended and recommended doses, after the seventh day the tested chemical pesticides killed more than 50% of IJs. With fenamiphos, the general means were 74.17 and 91.83%, respectively. Whereas abamectin was less toxic with the values of 42.83, 63.16 and increased to reach 74.00, 86.16 with oxamyl treatment. IJs of *H. bacteriophora* were found to be more tolerant to the tested compounds as compared to *S. carpocapsae* (Fig. 1). The two species, *S. carpocapsae* and *H. bacteriophora* had similar reaction to each of fenamiphos and oxamyl. Mortality percentages in *S. carpocapsae* and *H. bacteriophora* after the last day of the treatment were significantly different for all the tested materials. It means that the effect of this compound significantly varied with nematode species. Generally, results showed that abamectin was the least effective chemical pesticides against the two nematode species at the half and recommended doses.

Toxicity of Certain Biopesticides to Infective Juveniles of *S. carpocapsae* and *H. bacteriophora*.

Results in Table 2 show that one day after exposure, percent mortality of *S. carpocapsae* and *H. bacteriophora* in aqueous solutions of *T. album*, *B. megaterium*, and *S. marcescens* were 13.33, 8.67; 15.33, 10.33 and 14.00, 8.67%, respectively at the recommended field dose, while, the values for *S. carpocapsae* and *H. bacteriophora* at half recommended field dose were 11.00, 6.67; 10.00 , 5.33 and 9.67, 4.67 %, respectively.

Two days after exposure, at the recommended doses the percent mortality of *S. carpocapsae* and *H. bacteriophora* increased to reach 23.67 (18.00), 23.67 (19.00) and 23.33 (18.33) of *T. album*, *B. megaterium* and *S. marcescens*, respectively.

After seven days of EPNs, *S. carpocapsae,* and *H. bacteriophora* exposure to the recommended dose of biopesticides, *S. marcescens* gave the highest effect followed by *B. megaterium* while, *T. album* was the lowest effective one with general means of 63.00, 45.49 and 42.83%, respectively. A similar trend was obtained, when the two species of EPNs were exposed to the half-recommended dose of the above-mentioned biopesticides with general means of 43.66, 41.66 and 34.17%, respectively. Significant differences were existed in the level of tolerance between the two-nematode species against the tested biopesticides. Generally, it could be concluded that *S. carpocapsae* IJs was more sensitive to the tested biopesticides than *H. bacteriophora* and the biopesticides were less toxic to IJs of heterorhabditid and steinernematid nematodes as compared to the tested nematicides which were more toxic (Fig. 2).

Table 1. Mortality percent of IJs of *Steinernema carpocapsae* and *Heterorhabditis bacteriophora* after 1, 2, 4 and 7 days of exposuring to half recommended and recommended doses of certain chemical nematicides

Pesticide (Active ingredient)	Trade name/ Formulation	Concentration	Days after treatment	Nematode species		General mean
				S. carpocapsae	*H. bacteriophora*	
Abamectin	**Nemastop**	Half recommended	1	12.33 a	7.33 a	9.83
	(5% CS)	Recommended		16.67 c	11.00 d	13.83
		Half recommended	2	16.67 a	12.33 a	14.50
		Recommended		25.33 b	20.67 c	23.00
		Half recommended	4	39.00 b	28.00 b	33.50
		Recommended		50.67 a	39.33 b	45.00
		Half recommended	7	48.00 c	37.67 c	42.83
		Recommended		68.33 a	58.00 a	63.16
Fenamiphos	**Laguna**	Half recommended	1	16.67 c	12.00 a	14.33
	(40% EC)	Recommended		25.33 d	20.67 d	23.00
		Half recommended	2	23.00 b	17.33 a	20.16
		Recommended		39.67 c	35.33 c	37.50
		Half recommended	4	60.00 a	49.33 b	54.66
		Recommended		79.33 b	68.33 b	73.83
		Half recommended	7	79.67 a	68.67 c	74.17
		Recommended		92.67 a	91.00 a	91.83
Oxamyl	**Fydal**	Half recommended	1	22.67 a	17.67 a	20.17
	(24% SL)	Recommended		25.33 d	20.67 d	23.00
		Half recommended	2	31.33 a	26.67 a	29.00
		Recommended		40.67 c	36.00 c	38.33
		Half recommended	4	60.33 b	49.33 b	54.83
		Recommended		66.00 b	56.00 b	61.00
		Half recommended	7	79.33 c	68.67 c	74.00
		Recommended		91.33 a	81.00 a	86.16

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

Table 2. Mortality percent of IJs of *Steinernema carpocapsae* and *Heterorhabditis bacteriophora* after 1, 2, 4 and7 days of exposuring to half recommended and recommended dose of certain biopesticides

Biocide (Active ingredient)	Trade name/ Formulation	Concentration	Days after treatment	Nematode species		General mean
				S. carpocapsae	*H. bacteriophora*	
Bacillus megaterium	**Bio-arc (6% WP)**	Half recommended	1	10.00 a	5.33 a	7.66
		Recommended		15.33 a	10.33 d	12.66
		Half recommended	2	21.33 b	16.00 b	18.66
		Recommended		23.67 b	19.00 c	21.33
		Half recommended	4	32.67 c	25.67 c	29.17
		Recommended		41.67 c	30.67 b	36.17
		Half recommended	7	47.33 d	36.00 d	41.66
		Recommended		50.33 d	40.66 a	45.49
Trichoderma album	**Bio-zeid (2.5% WP)**	Half recommended	1	11.00 b	6.67 a	8.83
		Recommended		13.33 a	8.67 a	11.00
		Half recommended	2	15.67 b	10.67 a	13.17
		Recommended		23.67 b	18.00 b	20.83
		Half recommended	4	34.33 a	24.00 b	29.16
		Recommended		40.00 c	29.33 c	34.66
		Half recommended	7	37.67 a	30.67 c	34.17
		Recommended		47.67 d	38.00 d	42.83
Serratia marcescens	**Nemex (2% SL)**	Half recommended	1	9.67 b	4.67 a	7.17
		Recommended		14.00 a	8.67 a	11.33
		Half recommended	2	17.67 ab	13.00 b	15.33
		Recommended		23.33 b	18.33 b	20.83
		Half recommended	4	37.67 ab	34.00 c	35.83
		Recommended		54.67 c	44.33 c	49.50
		Half recommended	7	44.00 a	43.33 d	43.66
		Recommended		68.33 d	57.67 d	63.00

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

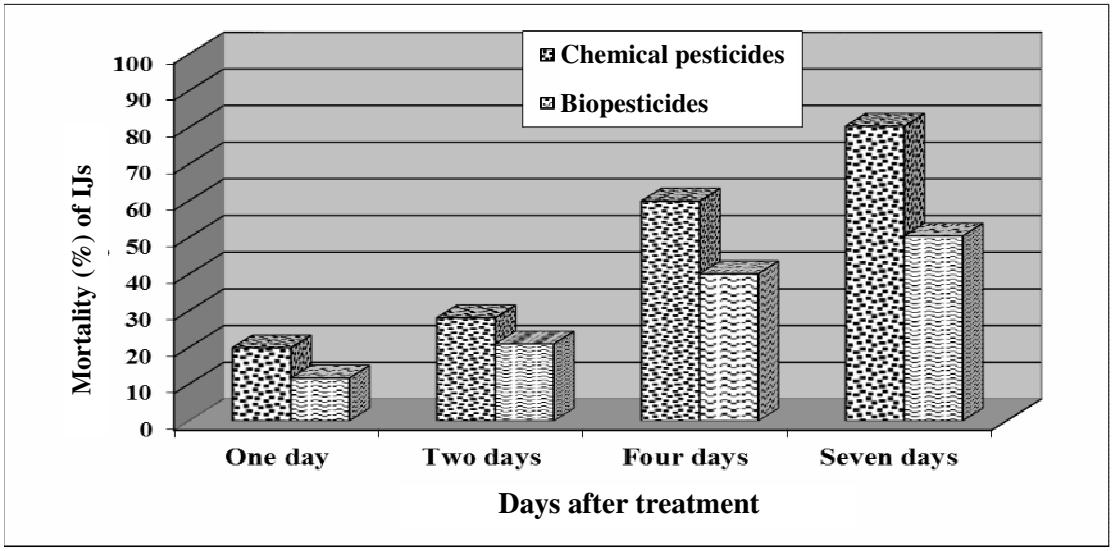

Fig.1. General means of mortality percentages of both nematode species, *Steinernema carpocapsae* and *Heterorhabditis bacteriophora* to tested chemical pesticides and biopesticides after one, two, four and seven days of exposure

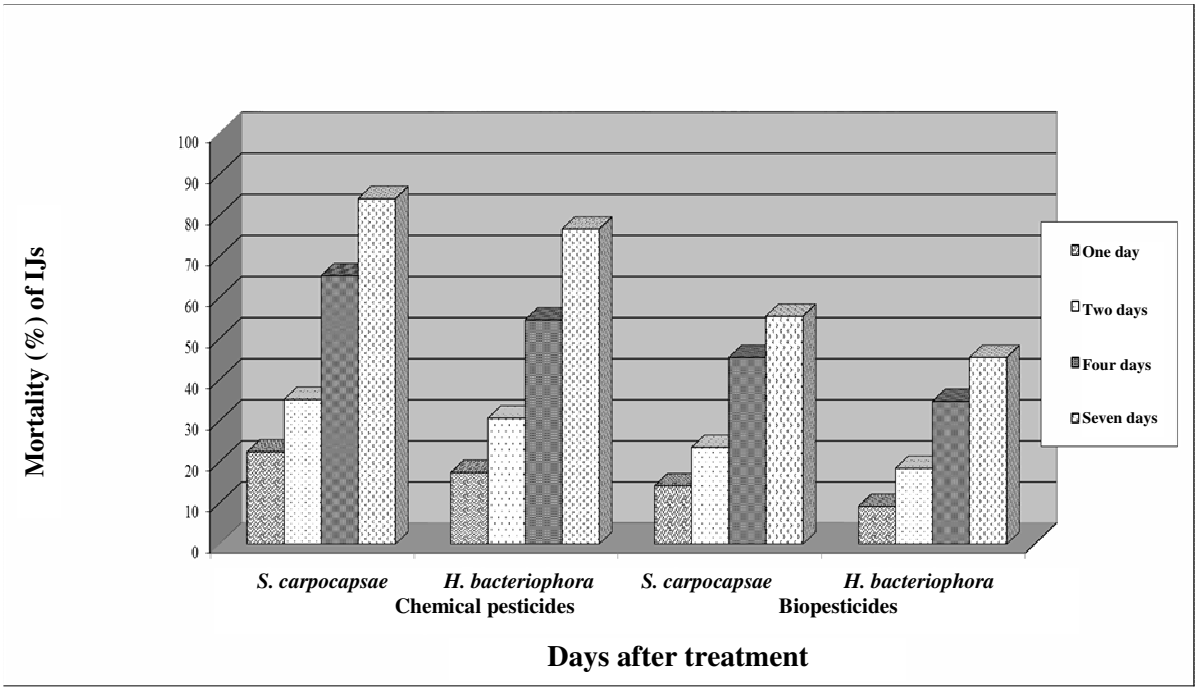

Fig. 2. Effect of various chemical pesticides and biopesticides on the survival of infective juveniles of *Steinernema carpocapsae* and *Heterorhabditis bacteriophora* after one, two, four and seven days of exposure

Nematodes and Pesticides Combinations

Results in Table 3 show that an additive effect took place when the recommended rate of fenamiphos was combined with *H. bacteriophora* species; C.F. values with *H. bacteriophora* was -14.49 and antagonism effect with *S. carpocapsae* species (C.F. = -22.37). Whereas it was found that, an additive effect took place when the recommended rate of abamectin was combined with *S. carpocapsae* and *H. bacteriophora* species, C.F. values were -5.69 and -13.86, respectively.

On the other hand, antagonism effect was noticed with the combination of oxamyl and *H. bacteriophora* giving C.F. value of -29.27, while the same nematicide showed additive effect with *S. carpocapsae* with C.F. values of -17.21.

It could be concluded that nematodes/ chemical pesticides combinations showed additive or antagonistic effects that depended on the bioactivity of the used nematicides and the susceptibility of the nematode species.

Nematodes and Biopesticides Combinations

The compatibility evaluation of combining the biopesticides *T. album*, *B. megaterium* and *S. marcescens* with *S. carpocapsae* and *H. bacteriophora* using co-toxicity factor bioassay showed either additive or antagonistic effect when the recommended rate of each biopesticide was applied simultaneously with the nematode species (Table 4). Combinations of *S. carpocapsae* and *H. bacteriophora* with *T. album* and *B. megaterium* displayed an additive effect on the 6th instar larvae of *G. mellonella* with C.F. values of +1.64, -9.31, -16.79 and -18.09, respectively. On the contrary, when *S. carpocapsae* and *H. bacteriophora* were applied with *S. marcescens*, an antagonistic effect was obtained with C.F. values -40.30 and -44.09, respectively. The previous results demonstrated the compatibility between entomopathogenic nematodes, *S. carpocapsae* and *H. bacteriophora* and formulations of the active ingredient of both nematicides, fenamiphos, abamectin and oxamyl and biopesticides, *T. albium*, *B. megaterium* and *S. marcescens*. It was found that some of these compounds are toxic and incompatible with entomopathogenic nematodes.

The organphosphorous nematicide, fenamiphos was the most toxic compound to *S. carpocapsae* and *H. bacteriophora*. **Hara and Kaya (1982)** found that such nematicide inhibited reproduction and development of the former nematode species when it was applied at 5 to 10 ppm which equal to field application rates and suggest that nematodes can be used before nematicides application to allow pesticide degradation over time. **Hara and Kaya (1983)** showed that IJs of *S. feltiae* were affected by fenamiphos and oxamyl. Also, 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; Rovesti and Deseo, 1990**).

Rovesti *et al*. (1988) emphasized that the greater concentration of pesticide might prevent the compatibility use of the chemical with *H. bacteriophora* nematode. **Mahfooz *et al*. (2008)** showed a nematicidal effect of abamectin on EPN species which may explain the relatively high mortality values. Whereas, **Laznik and Trdan (2013)** proved that *H. bacteriophora* was the species most tolerant to abamectin and *S. carpocapsae* was to be the most sensitive species. **Kovacs (1982)** suggested that emulsifiable formulates play an important role in the effect of pesticide on nematodes. **Kaya and Burlando (1989)** mentioned that placement of *S. feltiae* and *Galleria* on the sand surface at the same time with fenamiphos granules, totally suppressed activity of the nematodes. 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 and Wright, 1996**).

Infective juveniles (IJs) of EPN species can tolerate incompatible nematicides and biological pesticides by short-term exposure (2–24 hr.) and this varies depending upon the application volume and system used **(Alumai and Grewal, 2004). Grewal *et al*. (1998)** suggested that incompatible nematicides and insecticides can be used by wait 2 and 1 weeks after application, respectively.

In contrast, some reports revealed that oxamyl increased the efficacy of entomopathogenic nematodes. **Ishibashi (1993)** showed that oxamyl

Table 3. Compatibility evaluation of certain nematicides and entomopathogenic nematodes on mortality of the 6th instar larvae of great wax moth, *Galleria mellonella*

Chemical pesticides	Trade name/ Formulation	Nematode Species	Mortality (%) (Nematodes+pesticides)		Co-toxicity factor (CF)	Response
			Observed	Expected		
Abamectin	**Nemastop (5% CS)**	*S. carpocapsae*	63.33	69.02	-5.69	additive
		H. bacteriophora	80.00	93.86	-13.86	additive
Fenamiphos	**Laguna (40% EC)**	*S. carpocapsae*	66.66	85.66	-22.37	antagonism
		H. bacteriophora	76.66	89.66	-14.49	additive
Oxamyl	**Fydal (24% SL)**	*S. carpocapsae*	53.33	70.54	-17.21	additive
		H. bacteriophora	66.66	95.93	-29.27	antagonism

Table 4. Compatibility evaluation of certain biopesticides and entomopathogenic nematodes on mortality of the 6th instar larvae of great wax moth, *Galleria mellonella*

Biopesticides	Trade name/ Formulation	Nematode Species	Mortality (%) (Nematodes + pesticides)		Co-toxicity factor (CF)	Response
			Observed	Expected		
Bacillus megaterium	**Bio-arc (6% WP)**	*S. carpocapsae*	50.00	60.09	- 16.79	additive
		H. bacteriophora	66.66	81.39	- 18.09	additive
Trichoderma album	**Bio-zeid (2.5% WP)**	*S. carpocapsae*	60.00	58.36	+ 1.64	additive
		H. bacteriophora	70.00	79.31	- 9.31	additive
Serratia marcescens	**Nemex (2% SL)**	*S. carpocapsae*	36.66	61.41	- 40.30	antagonism
		H. bacteriophora	46.66	83.47	- 44.09	antagonism

increased *S. carpocapsae* efficacy against *Agrotis segatum* synergistically, but only in fumigated soil, probably by enhancing the nematode dictating behavior. **Nishimatsu and Jackson (1998)** showed that effective field results were obtained when many insecticides, including oxamyl, were simultaneously used with nematodes compared to the application of nematodes or insecticides alone.

Regarding biopesticides, **Raheel *et al.* (2017)** showed that the biopesticide, azadirachtin did not affect the survival of *S. feltiae* and *H. bacteriophora*. Moreover, it resulted that *H. bacteriophora* was the most tolerant species as compared to *S. feltiae*, *S. asiaticum* and *H. indica*. Likewise, similar finding was reported (**Radova, 2011; Laznik and Trdan, 2013**).

The need to test for the compatibility of EPNs and chemical pesticides or/and biopesticides is important when considering the use of EPNs in an IPM scheme. So, the EPNs with better compatibility with other chemical or biopesticides may be considered as a strong option for usage in IPM.

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توافق نوعي النيماتودا الممرضة للحشرات *Heterorhabditis bacteriophora* و *Steinernema carpocapsae* مع بعض المبيدات الكيميائية والحيوية

رمضان محمد أحمد العشري - عمرو محمد محمد المرزوقي

قسم وقاية النبات - كلية الزراعة – جامعة الزقازيق - مصر

تم تقييم تأثير ثلاثة مبيدات كيميائية (أبامكتين، فيناميفوس وأُكساميل) بالإضافة إلى ثلاثة مبيدات حيوية (بيو- أرك، بيو- زيد و نيمكس) بالمعدلات الموصي بها حقليا على نوعين من النيماتودا الممرضة للحشرات هما *Heterorhabditis bacteriophora* و *Steinernema carpocapsae* وكذلك تأثير خلط المبيدات سابقة الذكر على كفاءة نوعي النيماتودا في إصابة العمر اليرقي السادس لدودة الشمع الكبيرة تحت الظروف المعملية ، أوضحت النتائج أنه بعد يوم واحد من المعاملة خفضت المبيدات الكيميائية المستعملة من حيوية يرقات النيماتودا حيث تراوحت نسب الموت ما بين ٩,٨٣% إلى ٢٣,٠٠% إعتماداً على نوع المبيد ونوع النيماتودا، بعد يومين زادت نسبة موت يرقات النيماتودا بصورة واضحة لتصل إلى ٢٣,٠٠، ٣٧,٥٠ و٣٨,٣٣% مع الأبامكتين ،الفيناميفوس والاكساميل على التوالي، بينما سجلت النتائج الموازية فى اليوم السابع من التعرض للمبيدات السابقة مع كل من نصف التركيز الموصي به والتركيز الموصي به ٤٢,٨٣ (٦٣,١٦)، ٧٤,١٧ (٩١,٨٣) و٧٤,٠٠ (٨٦,١٦) % على التوالي، وكان مبيد الفيناميفوس هو الأكثر سمية يليه مبيد الأكساميل ثم الأبامكتين، أما عن تأثير مبيدات الآفات الحيوية (بيو- أرك، بيو- زيد و نيمكس) والتي كانت أقل سمية على يرقات النيماتودا المعدية لكل من *H. bacteriophora* و*S. carpocapsae* فقد وصلت نسبة الموت بعد اليوم السابع مع التركيز الموصى به ونصف الموصى به إلى ٤٥,٤٩ (٤١,٦٦)، ٤٢,٨٣ (٣٤,١٧) و٦٣,٠٠ (٤٣,٦٦) % مع بيو- أرك، بيو- زيد ونيمكس على التوالي، وكان أكثر مبيدات الآفات الحيوية المختبرة سمية هو مبيد نيمكس يليه مبيد بيو-أرك ثم بيو-زيد، أظهرت النتائج المتحَصل عليها والخاصة بتوافق هذه المبيداتَ مع نوعى النيماتودا الممرضة للحشرات في مكافحة العمر اليرقي السادس لدودة الشمع الكبيرة إلى حدوث تأثير إضافة أو تأثير تضاد وظهر تأثير الإضافة في أغلب المعاملات المختبرة بينما ظهر تأثير التضاد عند استخدام النوع *H. bacteriophora* مع الأكساميل والنوع *S. carpocapsae*، الفيناميفوس وكل من *S. carpocapsae* و*H. bacteriophora* مع المبيد نيمكس، وبصفة عامة يمكن التغلب على حالات عدم التوافق هذه باختيار الفترات الزمنية المناسبة بين النيماتودا والمعاملة بمبيدات الآفات .

المحكمـــــون:

١- أ.د. فاطمة عبد المحسن محمد مصطفى أستاذ الحيوان الزراعي – كلية الزراعة – جامعة المنصورة.

٢- أ.د. حسـني حامـد حسـني كسـبة أستاذ الحيوان الزراعي – كلية الزراعة – جامعة القاهرة.