EGYPTIAN ACADEMIC JOURNAL OF
BIOLOGICAL SCIENCES
ENTOMOLOGY

A

ISSN
1687-8809

WWW.EAJBS.EG.NET

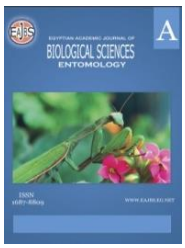
Vol. 14 No. 4 (2021)

Citation: *Egypt. Acad. J. Biolog. Sci. (A. Entomology) Vol. 14(4) pp.19-34 (2021)*
DOI: 10.21608/EAJBSA.2021.198979

Egypt. Acad. J. Biolog. Sci., 14(4):19-34(2021)

Egyptian Academic Journal of Biological Sciences
A. Entomology

ISSN 1687- 8809
http://eajbsa.journals.ekb.eg/



Compatibility of Native and Imported Entomopathogenic Nematodes with Different Applications of Insecticides for Controlling the Cigarette Beetle, *Lasioderma sericorne* Fabricius (Coleoptera: Anobiidae)

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ARTICLE INFO
Article History
Received:4/9/2021
Accepted:12/10/2021
Keywords:
Lasioderma sericorne. Entomopathogenic nematodes (EPNs), native strain, insecticides, application rates, compatibility

ABSTRACT

The cigarette beetle, *Lasioderma sericorne* Fabricius (Coleoptera: Anobiidae), is an important pest of stored products in the world which caused major economic losses that required many strategies for controlling insect pest. This study investigated native entomopathogenic nematodes (EPNs) and imported EPN species alone at different IJs concentrations or in combination with three application rates (recommended, quarter and half recommended concentrations) of lambda-cyhalothrin, emamectin benzoate and indoxacarb against the third and the fourth larval instars of its pest under laboratory conditions. The results showed that The native *H.bacteriophora* (Ar-4 strain) and the imported *H.bacteriophora* (HP88 strain) were more effective against the fourth larval instar of *L. sericorne* than the third instar followed by *S.carpocapsae* (All strain) while *H.bacteriophora* (Ba-1 strain) and *S. feltiae* strain were the least efficacy. According to LT_{50} of tested EPNs, 100 IJs/larva was the best concentration used against the larvae instars of *L. sericorne*. As well as, the fourth instar was more susceptible to the tested applications of pesticides than the third larval instar. Moreover, The application with a quarter recommended dose of indoxacarb was the most toxicity application against the fourth instar when compared to lambda-cyhalothrin and emamectin benzoate. On the other hand, the effects of the interactions between native and imported EPNs varied greatly as stated by application rates of tested insecticides and juveniles' concentration of EPNs. It is concluded that the best interaction effect was obtained with quarter recommended application (0.25 RC) of lambda-cyhalothrin when combined with EPNs at 100 IJs/larva ,which displayed synergistic effect to overcome incompatibility particularly with heterorhabditid species, the effect that could be beneficial when making progress the integrated program for stored-product pests.

INTRODUCTION

Larval stages feeding of stored grains caused the greatest damage to commodities particularly by widespread and destructive cigarette beetle, *Lasioderma sericorne* Fabricius (Coleoptera: Anobiidae) (Mahroof and Phillips, 2008). For a long time, phosphine was used in its control (Vincent and Lindgren, 1977; Rajendran *et al*., 2004 and Allahvaisi, 2013) which developed a significant level of resistance (Hori and Kasaishi,

2005; Saglam, Ö and Phillips 2015).

Nemours studies related to the use of bio-insecticides such as fungi (Saeed *et al*., 2017), essential oils (Wang *et al*.,2019 and Baccari *et al*.,2020) and entomopathogenic nematodes and fungi against the cigarette beetle, *L. serricorne*. Also, the effect of Steinernematidae and Heterorhabditidae strains of entomopathogenic nematodes were carried out against *Lasioderma serricorne* F. (Rumbos and Athanassiou, 2012; Negrisoli *et al*., 2013 and Khanum and Javed, 2021).

Numerous strategies were investigated against larval instar of *L. serricorne* including the use of strains of entomopathogenic nematodes (EPNs) belong to steinernematid and heterorhabditid species and other bio-pesticides products (Rumbos and Athanassiou, 2012). Free-living third-stage infective juveniles (IJs) of EPNs invade their hosts via natural body openings and they release their symbiotic mutualistic bacteria (*Xenorhabdus* in *Steinernema* and *Photorabdus* in *Heterorhabditis*) that caused death within a few days (Kaya and Gaugler, 1993 and Gaugler, 2002).

Native and imported species of steinernematidae and heterorhabditidae families have recently been evaluated against *L.serricorne.* For instance, (Rumbos and Athanassiou, 2012) tested the insecticidal effect of two against two strains of *Steinernema carpocapsae* Weiser and *Steinernema feltiae* Filipjev against the cigarette beetle, *L.serricorne*. Moreover, larvae and adults of other stored pests of *Anagasta kuehniella, Tenebrio molitor* and *Acanthoscelides obtectus*, *Sitophilus oryzae* and *Sitophilus zeamais* were exposed to eight strains of EPNs and virulence of EPN species/strains varied greatly according to the species of stored product pests (C.R. de Carvalho Barbosa Negrisoli *et al*.,2013). Nevertheless, most of the studies that are available for the use of EPNs in stored-product protection are based on the use of laboratory-reared strains, and not on commercial formulations.

Despite the controlling of this pest still relies on the use of pesticides, which is becoming less effective as the insect develops resistance. So, combining EPNs with pesticides is the main option for IPM programs against many agricultural pests (Koppenhöfer and Grewal,2005). This strategy has many advantages like reducing the requirement on chemicals and thus minimize the development of insecticide resistance and preventing adverse effects on man and the environment.

Application of bio-pesticides such as fungi and EPNs directly to grain storage bags for protection against stored grain pests is a novel approach for grain protection mainly with stored products in jute bags simulates the incorporation of deltamethrin into polypropylene bag to form ZeroFly® (Paudyal *et al*., 2016). However, there is an urgent need to evaluate the pathogenicity of fungus, *B. bassiana* and EPN species and doses used in the protection of bags.

Due to the great threat of key stored pests such as *L.serricorne*, researchers are interested in improving IPM programs by adopting friendly options for the environment and human health for controlling insect pests. In particular, biocontrol agents, employing natural enemies, such as entomopathogenic nematodes (EPNs) and low dosage of insecticides.

Therefore, the investigation aimed to study the efficiency of native and imported species/strains of EPNs against the 3rd and the 4th larval instars of *L. serricorne*. As well as, comparing varied logical doses (0.25 RD, 0.5 RD and RD, recommended dose) of three insecticides when combined with EPNs to establish the optimum compatibility application between each other for controlling this pest.

MATERIALS AND METHODS

Test Insects:

The larval instars of *Lasioderma serricorne* Fabricius used in experiments were reared at the Laboratory of Entomology, Department of Plant Protection, Zagazig University. All larval instars of *L. serricorne* were reared on artificial diets of wheat flour including 5% brewer's yeast (w/w) under the conditions of 28±2 °C and 70 ± 4% RH in continuous darkness containers. The third and fourth larval instars of *L. serricorne* were used in laboratory bioassays and interactions between entomopathogenic nematodes (EPNs) and diverse doses of insecticides experiments.

Entomopathogenic Nematodes (EPNs) Applied:

The tested EPNs were the imported *S.carpocapsae* (All strain) and *S. feltiae* (Filipjev strain) as well as three heterorhabditids, an imported species *H.bacteriophora* (HP88 strain) and three native species *H.bacteriophora* (Ar-4 strain), *H.bacteriophora* (Ba-1 strain) and *H. indica* strain which isolated formerly from El-Arish and Belbis district, Egypt by using the modified baiting technique of *Galleria mellonella* as described by (**EL-Ashry *et al*., 2018)**. The Abovementioned species were tested against the 3rd and the 4th larval instars of *L.serricorne*.

Propagation of EPNs:

Last larval instars of *Galleria mellonella* were used to propagate current EPNs species and new cultures less than one week old were used and EPN cultures were renewed by placing 2 filter papers (Whatmann No.1) in a 9-cm Petri dish. Five *G. mellonella* were placed in each Petri dish and the dish was covered. All EPNs cultures were placed on the laboratory bench and held at 25± 3 ºC for two days and dead larvae were transferred to white traps (Kaya and Stock, 1997). After 12-15 days, collected EPNs and their suspension were adjusted to 1000 IJs/ml and stored in shallow distilled water in transfer flasks at 12°C for up to 7 days prior to use.

Pesticides Used:

Recommended field concentration (RC), half recommended field concentration (0.5 RC) and quarter recommended field concentration (0.25 RC) of three commercial formulations of insecticides, emamectin benzoate **(**Avermectins insecticide, Known commercially as Excellent, 1.9 % EC, Kafr El Zayat Pesticides and Chemical Company, Egypt), Indoxacarb (Oxadiazine insecticide, Known commercially as Avaunt, 15 EC %, DuPont, USA) and Lambda-cyhalothrin (Pyrethroid insecticide, Known commercially as Lambda 10 % EC, DuPont, USA) were tested against the 3rd and the 4th larval instars of *L.serricorne* as well as, their compatibility and interactions with tested EPN species.

Bioassay Studies by EPNs:

Comparative infectivity of imported steinernematid species and three native isolates of *H.bacteriophora* were evaluated by using Petri dishes assay against the 3rd and the 4th larval instars of *L.serricorne* under laboratory conditions.

The Petri dishes (5-cm) are lined with two filter papers Whatmann No.1. Ten healthy of the 3rd or the 4th instar larvae were introduced in each Petri dish, then 0.5 ml of each nematode suspension contains about 50,100, 200 and 250 IJs/larva used to estimate the virulence of tested EPNs. Control Petri dishes received only distilled water. Each treatment was replicated five times and *L.serricorne* mortality was verified daily for 8 days of treatment. All dishes were placed in darkness chambers in the laboratory (27± 2ºC) at the aforementioned conditions. The lethal time (LT_{50}) of nematodes was estimated. The percentage of mortality was calculated according to the following equation: Mortality (%) = (Number of Dead larvae)/(Total number of larvae) × 100. To assess virulent of tested EPNs against *L.serricorne* 3rd and 4th instar larvae by Toxicity Index (TI) with

a concentration of 100 IJs/larvae, the data were subject to probity analysis (Finney, 1971) through a software computer program to obtain the LC_{50} and slope values. In addition, the efficiency of different compounds was measured by comparing the tested nematode with the most effective nematode using toxicity index (TI) which was calculated using the equation of Sun (Sun, 1950) as follows:

$$\mathrm{TI} = \frac{\mathrm{LC\ 50\ of\ A}}{\mathrm{LC\ 50\ of\ B}} x100$$

Where; A: the most effective nematode
B: the other tested nematode

Chemical Pesticides Studies:

Emamectin benzoate**,** indoxacarb and lambda-cyhalothrin were tested against the 3rd and the 4th larval instars of *L.serricorne* in Petri dishes assay. Recommended field concentration (RC), 0.5 RC and 0.25 RC of each pesticide were estimated against the 3rd and the 4th instar larvae of *L.serricorne*. Each Petri dish was lined with 2 filter paper of Whatmann No.1 and introduced five healthy of the third larval instars and the same way with the fourth larval instar of *L.serricorne*. Immediately, 1 ml of RC, 0.5 RC, or 0.25 RC was introduced to the 3rd or the 4th larval instars of *L.serricorne*. Control Petri dishes received clean distilled water only. As mentioned before, each treatment was replicated five times and *L.serricorne* mortality percentage was recorded daily. The lethal time (LT_{50}) of tested pesticides was calculated.

Combining the effect of Lowest EPNs Concentration (100 IJs/larva) with 0.5 RC or 0.25 RC of Tested Chemical Pesticides:

To evaluate the joint application of insecticides, emamectin benzoate**,** indoxacarb, and lambda-cyhalothrin and EPNs (100 IJs/larva) in controlling *L.serricorne,* ten active larval instars (3rd or 4th larval instars) were placed in 5-cm diameter Petri dishes lined with moist two filter paper. 0.5 ml of each nematode suspension was poured on filter paper together with 1 ml of each tested insecticide, which was applied in two different percentages of the recommended product dose, 0.5 RC, 0.25RC and recommended dose as a reference. Petri dishes were sealed tightly and incubated under the abovementioned laboratory conditions.

Control Petri dishes contained only ten larval instars of *L.serricorne* provided only with cleaned distilled water. Each of the third and the fourth larval instars treated with 0.5 RC or 0.25 RC of each tested chemical pesticide was replicated five times and *L.serricorne* mortality percentage was recorded daily. To the analysis of the interaction between steinernematid and heterorhabditid nematodes, the formula of (Richer, 1987 and Mansour *et al*., 1966) was used to estimate the Co-toxicity factor. The joint action was estimated using (Richer, 1987) formula:

$E = (X + Y) – XY/100$

Where E: the expected effect of the combination as well X and Y: the mortality percentages resulted of X and Y, respectively.

$$\mathrm{Co-toxicity\ Factor} = \frac{\mathrm{Observed\ effect\ (\%)} - \mathrm{Expected\ effect\ (\%)}}{\mathrm{Expected\ effect\ (\%)}} x100$$

The expected effect was compared with the actual effect obtained experimentally from the insecticide's interaction mixture according to (Mansour *et al*., 1966).

Three categories were used to classify the Co-toxicity factor effect. If Co-toxicity factor ≥ +20 is considered potentiation while ≤ -20 is considered as antagonism and -20: +20 indicated additive effect.

Statistical Analysis:

A complete randomized design was implemented in all experiments. Data were subjected to ANOVA using CoStat version 6.45. Means were compared by Tukey's test:

α = 0.05). The median lethal time (LT_{50}) values were calculated by probit analysis (Finney, 1971) using Analyst soft Biostat Pro V 5.8.4.3 Software.

RESULTS AND DISCUSSION

1-Pathogenicity of Different Entomopathogenic Nematodes (EPNs) Concentrations Against the Third and The Fourth Larval Instars of *Lasioderma serricorne* Fabricius under Laboratory Conditions:

a- Percentage of Mortality of The Third Larval Instar of *L. serricorne* :

The third instar larvae of *L. serricorne* treated with 50,100,200 and 250 IJs concentrations of entomopathogenic nematodes (EPNs) species demonstrated a significant level of mortality percentages with native and imported nematode species (Tukey's test: α= 0.05).The least mortality percentage was observed at 50 IJs/larva (12.0 %) with native *H.bacteriophora* (Ba-1) and imported *S. feltiae* (Filipjev) whereas, the high mortality percentages (22.0 and 28.0 %) were found with native *H.bacteriophora* (Ar-4) and imported *H.bacteriophora* (HP88) species, respectively at five days post-application. On the other hand, larvae mortality did not demonstrate significant differences between *S.carpocapsae* (All), *H.bacteriophora* (Ar-4) and *H. indica* at applied concentration 100IJs/larva with mortality percentages between 46 and 54 % as well as, the least mortality percent (16.0%) was achieved by *H.bacteriophora* (Ba-1) at five days post nematode application. Moreover, at 200 and 250 IJs applied concentrations, the high percentages of mortality ranged between 80.0 and 86.0 % with 200 IJs concentration after five days post nematode application in Petri dishes treated with native, *H.bacteriophora* (Ar-4) and imported heterorhabditid species, *H.bacteriophora* (HP88), respectively and the same trend was observed with concentration 250 IJs treatments.

No significant differences were observed in mortality percent at the concentration of 250 IJs between native and imported nematode species. Regarding mortality generated by native heterorhabditid species, *H.bacteriophora* (Ba-1) and imported *S. feltiae* (Filipjev), native *H.bacteriophora* (Ba-1) was the least effective species (72.0 %) followed by *S. feltiae* (Filipjev) with percent mortality of 82.0% without significant differences in each other (Table1).

Table 1. Mortality percentages of the third larval instar of *Lasioderma serricorne* Fabricius treated with four concentrations of imported steinernematid and heterorhabditid species compared with three native heterorhabditid species at 28± 2 °C and 70±4%RH.

Nematode species/strains	Percentage of mortality (%) of the 3rd instar larvae after five days of application			
	Nematode concentrations (IJs/larva)			
	50	**100**	**200**	**250**
S. carpocapsae (All)	24.0 ab	46.0 ab	72.0 ab	90.0 a
S. feltiae (Filipjev)	12.0 b	32.0 b	70.0 ab	82.0 ab
H.bacteriophora (HP88)	28.0 a	60.0 a	86.0 a	98.0 a
H.bacteriophora (Ar-4)	22.0 ab	54.0 ab	80.0 a	94.0 a
H. indica	20.0 ab	54.0 ab	76.0 a	90.0 a
H.bacteriophora (Ba-1)	12.0 b	16.0 ab	56.0 b	72.0 b

*Reported numbers represent means of 5 replicates with ten larvae.

**Same letter(s) in the same column are not differ significantly from each other (Tukey's test: α = 0.05).

b) **Percentage of Mortality of The Fourth Larval Instar of *L. serricorne***

At low EPNs concentrations (50 IJs/larvae), the percentages of mortality were observed in the 4th larval instar of *L. serricorne* treated with EPNs species and a significant level of mortality percent was demonstrated between native and imported nematode species (Tukey's test: α= 0.05). Mortality percent ranged between the least effective native EPNs species, *H.bacteriophora* (Ba-1) with 8.0% and the highest percentage of mortality (32.0%) with imported EPNs species, *H.bacteriophora* (HP88). On the other hand, the native heterorhabditid species, *H.bacteriophora* (Ar-4) and *H.indica* were more efficient against the fourth larval instar of *L. serricorne* than the third instar with mortalities percent 28.0 and 20.0 %, respectively after five days post-application.

Based on IJs/larva, larval mortality varied greatly according to nematode species. At concentration of 100 IJs/larva, the percentages of mortality in treatment of *S.carpocapsae* (All), *S. feltiae* (Filipjev), *H.bacteriophora* (HP88) , *H.bacteriophora* (Ar-4) *H. indica* and *H.bacteriophora* (Ba-1) were 50.0, 40.0 , 68.0 , 64.0, 48.0 and 24.0 % , respectively. Whereas a concentration of 200 IJs/larva, mortality percents generated by *H.bacteriophora* (HP88) and *H.bacteriophora* (Ar-4) were 92.0 and 80.0 % followed by *S.carpocapsae* (All) with 68.0% and *H.bacteriophora* (Ba-1) was the least effective one with mortality percent 50.0%. At 250 IJs/larva, the percentage of mortality reached 100.0% with imported and local EPNs, *H.bacteriophora* (HP88) and *H.bacteriophora* (Ar-4), respectively without insignificant mortality percent between *H.bacteriophora* (Ba-1) and *S. feltiae* (Filipjev) besides, *S.carpocapsae* (All), and *H. indica* with mortality percent 92.0 and 88.0%, respectively (Table2). According to data of percentages of mortality, native *H.bacteriophora* (Ar-4) and *H.bacteriophora* (HP88) were more effective against the fourth larval instar of *L. serricorne* than the third larval instar followed by *S.carpocapsae* (All). While *H.bacteriophora* (Ba-1) and *S. feltiae* (Filipjev) displayed the lowest pathogenicity effect against its pest and were not statistically different at the tested concentrations. These results finding agreed with (Ramos-Rodríguez *et al*., 2006 a, b) who explained that the differences in strains of EPNs can affect the mortality percent of *L.serricorne*. The native heterotahbditid species, *H.bacteriophora* (Ar-4) displayed effective results after imported nematode species, *H.bacteriophora* (HP88). Also, the larval instars were highly susceptible to *S. carpocapsae* (All) than *S. feltiae*. As well as, the efficacy of EPNs is determined by the life stage of the target species of pest (Mbata and Shapiro-Ilan, 2005 and Athanassiou *et al*., 2010).

Table 2. The Mortality percentages of the fourth larval instar of *Lasioderma serricorne* Fabricius treated with four concentrations of imported steinernematid and heterorhabditid species compared with three native heterorhabditid species at 28± 2 °C and 70±4%RH.

Nematode species/strains	Percentage of mortality (%) of the 4th larval instar after five days of application			
	Nematode concentrations (IJs/larva)			
	50	100	200	250
S.carpocapsae (All)	16.0 ab	50.0 bc	68.0 bc	92.0 ab
S. feltiae (Filipjev)	12.0 ab	40.0 cd	60.0 c	84.0 b
H.bacteriophora (HP88)	32.0 a	68.0 a	92.0 a	100.0 a
H.bacteriophora (Ar-4)	28.0 ab	64.0 ab	80.0 ab	100.0 a
H. indica	20.0 ab	48.0 bc	62.0 c	88.0 ab
H.bacteriophora (Ba-1)	8.0 b	24.0 d	50.0 c	80.0 b

*Reported numbers represent means of 5 replicates with ten larvae.

**Same letter(s) in the same column are not differ significantly from each other (Tukey's test: α = 0.05).

c- LT50 and Slope Values of 100 IJs of Nematode Strains Tested against the Third and Fourth Larval Instars of Cigarette Beetle, *L.serricorne*:

The mortality percent of larval instars of *L.serricorne* reached 50% by a concentration of 100 IGs/ larvae EPNs and differed significantly according to different nematode strains. The lethal time (LT_{50}) and the toxicity index (TI) were calculated further in (Table 3). The *H.bacteriophora* (HP88) was the most virulent nematode with LT_{50} and TI values were 3.352 ± 0.714 (3.547 ± 0.674) and 100 (100) against the third and fourth larval instars of *L.serricorne* followed by local EPN species, *H.bacteriophora* (Ar-4) with the parallel values were 3.704 ± 0.408 (3.902 ± 0.684) and 90.496 (90.902), respectively then followed by *S.carpocapsae* (All) with LT_{50} and TI values were 3.842 ± 0.684(4.015 ± 0.408) and 87.246 (88.343). Conversely, *H.bacteriophora* (Ba -1) ranked as the least virulent nematode with LT_{50} and TI values were 4.636 ± 0.325 (4.762 ± 0.796) and 72.303 (74.485) with the 3rd and 4th larval instars, respectively. Slope values for tested EPNs against the third and fourth larval instars of *L. serricorne* were 2.933(2.121), 2.786 (3.061), 4.557 (3.258), 2.461(3.408), 1.895(3.524) and 3.124(3.449) with *S.carpocapsae* (All), *S. feltiae* (Filipjev), *H.bacteriophora* (HP88), *H.indica* , *H.bacteriophora* (Ar- 4) and *H.bacteriophora* (Ba -1), respectively. Moreover, the concentration of 100 IJs/larva was the best concentration used according to LT50 for killing the third and the fourth larval instars of *L. serricorne*

Generally, EPNs concentration of 100/IJs was more potential than 200 IJs per 3rd and 4th larval instars of *L.serricorne* is agreed with by (Khanum and Javed,2021) when tested Pakistani isolates of Steinernematidae against stored grain pests *L. serricorne* and *Tribolium castaneum*.

Table 3: LT_{50} and slope values of 100 IJs *S.carpocapsae* (All strain), *S. feltiae* (Filipjev), *H.bacteriophora* (HP88), *H.bacteriophora* (Ar-4), *H.indica* and *H.bacteriophora* (Ba-1) tested against the third and fourth larval instars of cigarette beetle, *Laseioderma serricorne* Fabricius.

Nematode species	The 3th larval instar of *L. serriform*			The 4th larval instar of *L.serricorne*		
	LT_{50}	Slope ± SE	TI	LT_{50}	Slope± SE	TI
S.carpocapsae (All)	3.842 ± 0.684	2.933	87.246	4.015 ± 0.408	2.121	88.343
S. feltiae (Filipjev)	4.578± 0.254	2.786	73.219	4.395 ± 0.684	3.061	80.705
H.bacteriophora (HP88)	3.352 ± 0.714	4.557	100.00	3.547 ± 0.674	3.258	100.00
H.bacteriophora (Ar- 4)	4.210 ± 0.521	2.461	79.619	4.687± 0.684	3.408	75.677
H.indica	3.704 ± 0.408	1.895	90.496	3.902 ± 0.684	3.524	90.902
H.bacteriophora (Ba -1)	4.636 ± 0.325	3.124	72.303	4.762 ± 0.796	3.449	74.485

* The LT_{50} values express median lethal time ± standard error.

2- Insecticidal Efficacy of Lambda-Cyhalothrin, Emamectin Benzoate and Indoxacarb Against the Third and Fourth Larval Instars of *L.serricorne*:

From current results in Table 4, pesticides were more effective against the fourth than the third larval instars at three tested doses. Concerning the 3rd larval instar of *L. serricorne*, the mortality percent caused by 0.25, 0.5 and RC doses of tested insecticides varied greatly according to insecticide. Regarding 0.25 RC, the mortality percent remained at low levels with lambda-cyhalothrin (16.0%), emamectin benzoate (26.0%) and indoxacarb (40.0%), respectively and increased to reach 30.0, 46.0 and 54.0 % with the mentioned insecticides, respectively. After exposure to 0.5RC, the mortality percent in treatments of 3rd larval instar ranged from 50.0 to 72 % and from 58.0 to 76.0% with the 4th larval instar of *L. serricorne*. At recommended field concentration (RC), the percentage of mortality in the 4th larval instar reached 100% after exposure to indoxacarb while the mortality percent in treatments of the 3rd larval instar did not exceed 78%. The

results showed that the three rates (quarter, half and recommended doses) of insecticides had relatively high mortality on larval instars of the cigarette beetle. There were no significant differences (α = 0.05) between emamectin benzoate and indoxacarb. Moreover, at 0.25 RC, lambda-cyhalothrin was the least toxic insecticidal against the 3rd and 4th larval instars of *L. serricorne*. Regarding the toxicity of tested pesticides, results showed that three tested application rates were more effective against the fourth larval instar than the third larval instar of *L. serricorne*. Moreover, 0.25 RC of indoxacarb was the most toxicity application rates against the fourth larval instar of *L. serricorne*, when compared with lambda-cyhalothrin and emamectin benzoate besides to, the mortality percent in the fourth larval instar reached 100% after exposure to indoxacarb while mortality percent in treatments of the third larval instar did not exceed 78%. Generally, the tested insecticide, indoxacarb was used in controlling various insect pests in agricultural and urban settings (Wing *et al*., 1998 and Wing *et al*., 2000). EPNs are generally more slow-acting in comparison with most traditional insecticides that are used as grain protectants. Hence, delayed mortality of the exposed individuals may result in mating and oviposition before death, which may lead to a continuance of grain damage (Moore *et al*., 2000).

Table 4. Percentage of mortality of the third and fourth larval instars of *Laseioderma serricorne* Fabricius after treatment of 0.25RC, 0.5 RC and recommended field concentration (RC) of three insecticides used in their control under laboratory conditions.

Insecticides	The 3rd larval instar of *L.serricorne*			The 4th larval instar of *L.serricorne*		
	0.25 RC	0.5 RC	RC	0.25 RC	0.5 RC	RC
Lambda- cyhlothrin	16.0 c	50.0 c	78.0 b	30.0 b	58.0 abc	88.0 ab
Emmectin benzoate	26.0 c	62.0 bc	90.0 ab	46.0 b	68.0 ab	90.0 ab
Indoxycarb	40.0 a	72.0 ab	96.0 a	54.0 b	76.0 a	100.0 a

*Reported numbers represent means of 5 replicates with ten larvae.
**Same letter(s) in the same column are not differ significantly from each other (Tukey's test: α = 0.05).

B. Effect of Insecticides- EPNs Combinations on Larval Mortality of *L.serricorne* :

B1. Effect of 0.25 RC, 0.5 RC and RC of Lambda-cyhalothrin on EPNs–Combinations against *L. serricorne* larvae:

B.1.1. At Concentration of 100 IJs.:

Percentages of mortality of the third and the fourth larval instars of *L.serricorne* treated with lambda-cyhalothrin combinations at different recommended field concentration (RC), 0.25RC, 0.5RC and RC are shown in Table 5. Application of 0.25 RC lambda-cyhalothrin and EPN species against the fourth larval instar of *L.serricorne* displayed synergistic effect with all EPNs species while in treatment of the third larval instar , additive effect showed only with *H. indica* and *H.bacteriophora* (Ba-1). Application of 0.5 RC lambda-cyhalothrin and EPN species against the third larval instar of *L.serricorne* displayed additive effect and synergistic effect displayed only with *S. feltiae* (Filipjev) and *H.bacteriophora* (Ba-1) in treatment of the fourth larval instar. Application of RC lambda-cyhlothrin and EPN species against larvae of *L.serricorne* displayed antagonism effect while additive effect was observed in interaction between *H.bacteriophora* (HP88) and lambda-cyhalothrin with the fourth larval instar of *L.serricorne.* Generally, the synergistic effect was inversely proportion to recommended field concentration (RC) of lambda-cyhalothrin. On the other hand, proportion of additive

and antagonism effect increased from 0.5 RC to RC lambda-cyhalothrin with all the tested EPN species. Co-toxicity factors (CF) varied greatly according to RC of lambda-cyhalothrin and nematode species (Table 5).

Table 5. Interactions between steinernematid and heterorhabditid species at a concentration of 100 IJs with three recommended field concentrations (RC) of Lambda- cyhalothrin against the third and fourth larval instars of *Laseioderma serricorne* Fabricius.

Insecticide	Nematode species	The 3rd instar larvae					The 4th instar larvae			
		Application rates (µg a.i/ml)	Observed mortality (%)	C.F.	Expected mortality (%)	Interaction	Observed mortality (%)	C.F.	Expected mortality (%)	Interaction
Lambda-cyhlothrin	*S. carpocapsae* (All)	0.25 RC	76.0	22.19	62.20	Synergistic	78.0	38.49	56.32	Synergistic
	S. feltiae (Filipjev)	0.25 RC	72.0	37.40	52.40	Synergistic	74.0	49.19	49.60	Synergistic
	H.bacteriophora (HP88)	0.25 RC	88.0	22.22	72.00	Synergistic	90.0	23.09	73.12	Synergistic
	H.bacteriophora (Ar-4)	0.25 RC	84.0	21.39	69.20	Synergistic	88.0	26.15	69.76	Synergistic
	H. indica	0.25 RC	70.0	3.24	67.80	Additive	72.0	27.84	56.32	Synergistic
	H.bacteriophora (Ba-1)	0.25 RC	68.0	17.24	58.00	Additive	64.0	76.99	36.16	Synergistic
	S. carpocapsae (All strain)	0.5 RC	82.0	6.05	77.32	Additive	88.0	18.92	74.00	Additive
	S. feltiae (Filipjev)	0.5 RC	76.0	6.38	71.44	Additive	86.0	22.86	70.00	Synergistic
	H.bacteriophora (HP88)	0.5 RC	92.0	10.58	83.20	Additive	94.0	11.90	84.00	Additive
	H.bacteriophora (Ar-4)	0.5 RC	90.0	10.40	81.52	Additive	88.0	7.32	82.00	Additive
	H. indica	0.5 RC	74.0	-8.28	80.68	Additive	78.0	5.41	74.00	Additive
	H.bacteriophora (Ba-1)	0.5 RC	80.0	6.95	74.80	Additive	84.0	35.48	62.00	Synergistic
	S. carpocapsae (All strain)	RC	68.0	-27.29	93.52	Antagonism	62.0	-29.99	88.56	Antagonism
	S. feltiae (Filipjev)	RC	64.0	-30.31	91.84	Antagonism	58.0	-33.18	86.80	Antagonism
	H.bacteriophora (HP88)	RC	74.0	-22.27	95.20	Antagonism	78.0	-16.09	92.96	Additive
	H.bacteriophora (Ar-4)	RC	72.0	-23.99	94.72	Antagonism	68.0	-26.15	92.08	Antagonism
	H. indica	RC	62.0	-34.38	94.48	Antagonism	66.0	-25.47	88.56	Antagonism
	H.bacteriophora (Ba-1)	RC	56.0	-39.66	92.80	Antagonism	48.0	-42.36	83.28	Antagonism

B.1.2. At Concentration of 200 IJs.:

From Table (6), it was true with the tested EPN species, increase concentration to 200 IJs obviously not companied with an increase in mortality percent of the third and the fourth larval instars of *L.serricorne* at the three application rates of lambda-cyhalothrin. Application of 0.25 RC lambda-cyhalothrin and EPN species against the third and the fourth larval instars of *L.serricorne* displayed additive effect with all EPNs species except with *H. indica* which displayed synergistic effect. Application of 0.5 RD lambda-cyhalothrin and EPN species against tested instar larvae of *L.serricorne* displayed additive effect while antagonistic effect displayed with EPNs at recommended field concentration (RC) of lambda-cyhalothrin.

Generally, the synergistic effect was completely disappeared except with *H. indica* . As well as, antagonistic effect companied with an increase in lambda-cyhalothrin field concentration. On the other hand, CF varied greatly according to tested RC of lambda-cyhalothrin and nematode species (Table 6).

Table 6. Interactions between steinernematid and heterorhabditid species at a concentration of 200 IJs with three recommended field concentrations (RC) of Lambda- cyhalothrin against the third and fourth larval instars of *Laseioderma serricorne* Fabricius.

Insecticide	Nematode species	The 3rd instar larvae					The 4th instar larvae			
		Application rates (µg a.i/ml)	Observed mortality (%)	C.F.	Expected mortality (%)	Interaction	Observed mortality (%)	C.F.	Expected mortality (%)	Interaction
Lambda- cyhlothrin	*S. carpocapsae* (All)	0.25 RC	76.0	-3.80	79.00	Additive	78.0	6.67	73.12	Additive
	S. feltiae (Filipjev)	0.25 RC	72.0	4.05	69.20	Additive	74.0	11.45	66.40	Additive
	H.bacteriophora (HP88)	0.25 RC	88.0	-2.44	90.20	Additive	90.0	-3.52	93.28	Additive
	H.bacteriophora (Ar-4)	0.25 RC	84.0	0.96	83.20	Additive	88.0	5.77	83.20	Additive
	H. indica	0.25 RC	70.0	-18.60	86.00	Additive	72.0	20.64	59.68	Synergistic
	H.bacteriophora (Ba-1)	0.25 RC	68.0	-15.42	80.40	Additive	64.0	10.34	58.00	Additive
	S. carpocapsae (All strain)	0.5 RC	82.0	-6.18	87.40	Additive	88.0	4.76	84.00	Additive
	S. feltiae (Filipjev)	0.5 RC	76.0	-6.77	81.52	Additive	86.0	7.50	80.00	Additive
	H.bacteriophora (HP88)	0.5 RC	92.0	-2.25	94.12	Additive	94.0	-2.08	96.00	Additive
	H.bacteriophora (Ar-4)	0.5 RC	90.0	0.09	89.92	Additive	88.0	-2.22	90.00	Additive
	H. indica	0.5 RC	74.0	-19.21	91.60	Additive	78.0	2.63	76.00	Additive
	H.bacteriophora (Ba-1)	0.5 RC	80.0	-9.34	88.24	Additive	84.0	12.00	75.00	Additive
	S. carpocapsae (All strain)	RC	68.0	-29.46	96.40	Antagonistic	62.0	-33.30	92.96	Antagonistic
	S. feltiae (Filipjev)	RC	64.0	-32.43	94.72	Antagonistic	58.0	-36.40	91.20	Antagonistic
	H.bacteriophora (HP88)	RC	74.0	-24.74	98.32	Antagonistic	78.0	-20.60	98.24	Antagonistic
	H.bacteriophora (Ar-4)	RC	72.0	-25.86	97.12	Antagonistic	68.0	-28.87	95.60	Antagonistic
	H. indica	RC	62.0	-36.48	97.60	Antagonistic	66.0	-26.21	89.44	Antagonistic
	H.bacteriophora (Ba-1)	RC	56.0	-42.05	96.64	Antagonistic	48.0	-46.07	89.00	Antagonistic

C1. Effect of 0.25 RC, 0.5 RC and RC Emamectin benzoate on EPNs–Combinations against the Larval Instars of *L. sericorne*:

C.1.1. At A Concentration of 100 IJs:

Mortality percenters of the third and the fourth larval instars of *L.serricorne* treated with emamectin benzoate combinations at different recommended field concentrations (RC), 0.25RC, 0.5RC and RC are shown in Table 7. An additive effect was obtained with the third larval instar after treatment with 0.25 RC of emamectin benzoate combined with 100 IJs of all EPN species not including native nematode, *H.bacteriophora* (Ar-4) whereas, in treatment of the fourth larval instar, a synergistic effect was assessed with all tested EPNs not including native nematode, *H. indica.* Application of 0.5 RD emamectin benzoate and EPN species against the third and the fourth larval instars of *L.serricorne* displayed additive effect and synergistic effect displayed only with *H.bacteriophora* (Ar-4) in treatment of the third larval instar. Application of RC emamectin benzoate and EPN species against larvae of *L.serricorne* displayed antagonism effect and the only additive effect was observed in the interaction between *H.bacteriophora* (HP88) and emamectin benzoate with the fourth larval instar of *L.serricorne.* Among the three recommended field concentrations of emamectin benzoate, 0.25 RC gave the best results (synergistic and additive effect) followed by 0.5 RC (additive effect) while three recommended field concentrations (RC) showed mostly antagonistic. Also, Co-toxicity factors (CF) varied greatly according to RC of emamectin benzoate and nematode species (Table 7).

C.1.2. At Concentration of 200 IJs.

Application of 0.25 and 0.5 RC of emamectin benzoate showed additive effect with the third and the fourth larval instars of *L.serricorne* and only antagonistic effect displayed with native nematode species, *H. indica.* From (Table 8), it was true with the tested EPN species, the increased concentration to 200 IJs obviously did not companied with an increase in mortality percent of the third and the fourth larval instars of *L.serricorne* at the three RC emamectin benzoate. Moreover, All EPN species showed an antagonistic effect when applied with recommended field concentration (RC) of emamectin benzoate against the third and the fourth larval instars of *L.serricorne* . Generally, the synergistic effect was completely disappeared except with *H. indica*. As well as, antagonistic effect companied with an increase in emamectin benzoate field concentration. On the other hand,

CF varied greatly according to tested RC of lambda-cyhalothrin and nematode species. Among the three recommended field concentrations of emamectin benzoate, 0.25 RC gave the best results (synergistic and additive effect) followed by 0.5 RC (additive effect) while three recommended field concentrations (RC) showed mostly antagonistic. Obviously, all tested application rates were greatly varied in their effect on tested EPN species and 0.25 RC was the best acceptable application rate in combination with each other.

Table 7. Interactions between steinernematid and heterorhabditid species at a concentration of 100 IJs with three recommended field concentrations (RC) of Emamectin benzoate against the third and fourth larval instars of *Laseioderma serricorne* Fabricius.

Insecticide	Nematode species	The 3rd instar larvae					The 4th instar larvae			
		Application rates (µg a.i/ml)	Observed mortality (%)	C.F.	Expected mortality (%)	Interaction	Observed mortality (%)	C.F.	Expected mortality (%)	Interaction
Emmectin benzoate	*S. carpocapsae* (All)	0.25 RC	76.0	7.28	70.84	Additive	78.0	26.79	61.52	Synergistic
	S. feltiae (Filipjev)	0.25 RC	72.0	13.78	63.28	Additive	74.0	33.09	55.60	Synergistic
	H.bacteriophora (HP88)	0.25 RC	88.0	12.24	78.40	Additive	90.0	22.68	73.36	Synergistic
	H.bacteriophora (Ar-4)	0.25 RC	84.0	53.73	54.64	Synergistic	88.0	43.04	61.52	Synergistic
	H. indica	0.25 RC	70.0	-6.87	75.16	Additive	72.0	-5.66	76.32	Additive
	H.bacteriophora (Ba-1)	0.25 RC	68.0	-9.53	75.16	Additive	64.0	46.25	43.76	Synergistic
	S. carpocapsae (All strain)	0.5 RC	82.0	-0.87	82.72	Additive	88.0	9.67	80.24	Additive
	S. feltiae (Filipjev)	0.5 RC	76.0	-2.86	78.24	Additive	86.0	11.40	77.20	Additive
	H.bacteriophora (HP88)	0.5 RC	92.0	5.50	87.20	Additive	94.0	8.90	86.32	Additive
	H.bacteriophora (Ar-4)	0.5 RC	90.0	23.09	73.12	Synergistic	88.0	9.67	80.24	Additive
	H. indica	0.5 RC	74.0	-13.23	85.28	Additive	78.0	2.20	76.32	Additive
	H.bacteriophora (Ba-1)	0.5 RC	80.0	-6.19	85.28	Additive	84.0	18.11	71.12	Additive
	S. carpocapsae (All strain)	RC	68.0	-28.12	94.60	Antagonistic	62.0	-34.60	94.80	Antagonistic
	S. feltiae (Filipjev)	RC	64.0	-31.33	93.20	Antagonistic	58.0	-38.30	94.00	Antagonistic
	H.bacteriophora (HP88)	RC	74.0	-22.92	96.00	Antagonistic	78.0	-19.09	96.40	Additive
	H.bacteriophora (Ar-4)	RC	72.0	-21.40	91.60	Antagonistic	68.0	-28.27	94.80	Antagonistic
	H. indica	RC	62.0	-35.01	95.40	Antagonistic	66.0	-31.82	96.80	Antagonistic
	H.bacteriophora (Ba-1)	RC	56.0	-41.30	95.40	Antagonistic	48.0	-48.05	92.40	Antagonistic

Table 8. Interactions between steinernematid and heterorhabditid species at a concentration of 200 IJs with three recommended field concentrations (RC) of Emamectin benzoate against the third and fourth larval instars of *Laseioderma serricorne* Fabricius.

Insecticide	Nematode species	The 3rd instar larvae					The 4th instar larvae			
		Application rates (µg a.i/ml)	Observed mortality (%)	C.F.	Expected mortality (%)	Interaction	Observed mortality (%)	C.F.	Expected mortality (%)	Interaction
Emmectin benzoate	*S. carpocapsae* (All)	0.25 RC	76.0	-9.31	83.80	Additive	78.0	2.20	76.32	Additive
	S. feltiae (Filipjev)	0.25 RC	72.0	-5.56	76.24	Additive	74.0	5.11	70.40	Additive
	H.bacteriophora (HP88)	0.25 RC	88.0	-4.80	92.44	Additive	90.0	-4.34	94.08	Additive
	H.bacteriophora (Ar-4)	0.25 RC	84.0	-3.49	87.04	Additive	88.0	3.29	85.20	Additive
	H. indica	0.25 RC	70.0	-21.52	89.20	Antagonistic	72.0	11.66	64.48	Additive
	H.bacteriophora (Ba-1)	0.25 RC	68.0	-19.89	84.88	Additive	64.0	1.59	63.00	Additive
	S. carpocapsae (All strain)	0.5 RC	82.0	-9.29	90.40	Additive	88.0	0.18	87.84	Additive
	S. feltiae (Filipjev)	0.5 RC	76.0	-11.55	85.92	Additive	86.0	1.42	84.80	Additive
	H.bacteriophora (HP88)	0.5 RC	92.0	-3.69	95.52	Additive	94.0	-3.05	96.96	Additive
	H.bacteriophora (Ar-4)	0.5 RC	90.0	-2.51	92.32	Additive	88.0	-4.76	92.40	Additive
	H. indica	0.5 RC	74.0	-20.94	93.60	Antagonistic	78.0	-4.60	81.76	Additive
	H.bacteriophora (Ba-1)	0.5 RC	80.0	-12.13	91.04	Additive	84.0	3.70	81.00	Additive
	S. carpocapsae (All strain)	RC	68.0	-29.90	97.00	Antagonistic	62.0	-35.95	96.80	Antagonistic
	S. feltiae (Filipjev)	RC	64.0	-33.05	95.60	Antagonistic	58.0	-39.58	96.00	Antagonistic
	H.bacteriophora (HP88)	RC	74.0	-24.95	98.60	Antagonistic	78.0	-21.37	99.20	Antagonistic
	H.bacteriophora (Ar-4)	RC	72.0	-26.23	97.60	Antagonistic	68.0	-30.61	98.00	Antagonistic
	H. indica	RC	62.0	-36.73	98.00	Antagonistic	66.0	-30.67	95.20	Antagonistic
	H.bacteriophora (Ba-1)	RC	56.0	-42.39	97.20	Antagonistic	48.0	-49.47	95.00	Antagonistic

D1. Effect of 0.25 RC, 0.5 RC and RC Indoxacarb on EPNs–Combinations against *L. serricorne* Larvae*:*

D.1.1. At A Concentration of 100 IJs:

Native EPN species, *H.bacteriophora* (Ar-4) showed a synergistic effect and other imported or native nematode species showed additive effect against the third and the fourth larval instars of *L.serricorne* when combined with 0.25 RC of indoxacarb. Also, combinations between imported and native EPN species displayed additive effects at 0.5 RC of indoxacarb. Contrarily, the antagonistic effect appeared with all nematode species except with imported species, *H.bacteriophora* (HP88) in treatment of the fourth larval instar of *L.serricorne.*

From current results, application rate 0.25 RC was the most acceptable application rate in combination between nematodes and indoxacarb (Table 9).

Table 9. Interactions between steinernematid and heterorhabditid species at a concentration of 100 IJs with three recommended field concentrations (RC) of indoxacarb against the third and fourth larval instars of *Laseioderma serricorne* Fabricius.

Insecticide	Nematode species	The 3rd instar larvae					The 4th instar larvae			
		Application rates (µg a.i/ml)	Observed mortality (%)	C.F.	Expected mortality (%)	Interaction	Observed mortality (%)	CF.	Expected mortality (%)	Interaction
Indoxycarb	*S. carpocapsae* (All)	0.25 RC	76.0	1.12	75.16	Additive	78.0	13.37	68.80	Additive
	S. feltiae (Filipjev)	0.25 RC	72.0	4.77	68.72	Additive	74.0	15.63	64.00	Additive
	H.bacteriophora (HP88)	0.25 RC	88.0	7.84	81.60	Additive	90.0	14.80	78.40	Additive
	H.bacteriophora (Ar-4)	0.25 RC	84.0	36.90	61.36	Synergistic	88.0	27.91	68.80	Synergistic
	H. indica	0.25 RC	70.0	-11.21	78.84	Additive	72.0	-10.89	80.80	Additive
	H.bacteriophora (Ba-1)	0.25 RC	68.0	-13.75	78.84	Additive	64.0	17.65	54.40	Additive
	S. carpocapsae (All strain)	0.5 RC	82.0	-5.79	87.04	Additive	88.0	3.00	85.44	Additive
	S. feltiae (Filipjev)	0.5 RC	76.0	-9.18	83.68	Additive	86.0	3.37	83.20	Additive
	H.bacteriophora (HP88)	0.5 RC	92.0	1.77	90.40	Additive	94.0	4.54	89.92	Additive
	H.bacteriophora (Ar-4)	0.5 RC	90.0	12.73	79.84	Additive	88.0	3.00	85.44	Additive
	H. indica	0.5 RC	74.0	-16.82	88.96	Additive	78.0	-14.32	91.04	Additive
	H.bacteriophora (Ba-1)	0.5 RC	80.0	-10.07	88.96	Additive	84.0	6.71	78.72	Additive
	S. carpocapsae (All strain)	RC	68.0	-32.00	100	Antagonistic	62.0	-34.60	94.80	Antagonistic
	S. feltiae (Filipjev)	RC	64.0	-36.00	100	Antagonistic	58.0	-38.30	94.00	Antagonistic
	H.bacteriophora (HP88)	RC	74.0	-26.00	100	Antagonistic	78.0	-19.09	96.40	Additive
	H.bacteriophora (Ar-4)	RC	72.0	-28.00	100	Antagonistic	68.0	-28.27	94.80	Antagonistic
	H. indica	RC	62.0	-38.00	100	Antagonistic	66.0	-31.82	96.80	Antagonistic
	H.bacteriophora (Ba-1)	RC	56.0	-44.00	100	Antagonistic	48.0	-48.05	92.40	Antagonistic

D.1.2. At Concentration of 200 IJs.

From (Table 10), native EPN species varied in their interaction effect according to species and indoxacarb application rate. For instance, *H.bacteriophora* (Ar-4) and *H.bacteriophora* (Ba-1) showed additive effect while antagonistic with *H. indica* in the treatment of the third larval instar at application rates 0.25 RC and 0.5 RC. Whereas with the fourth larval instar of *L.serricorne*, all nematode species showed an additive effect. Unfortunately, at recommended field concentration (RC), all EPN species displayed antagonistic effects and varied greatly in CF.

Generally, the synergistic effect was completely disappeared and the additive or antagonistic effect companied with the increase in indoxacarb recommended field concentration (RC).

The Best interaction effect was obtained with 0.25 RC of lambda-cyhalothrin at a concentration of 100 IJs/larva of EPNs, which displayed synergistic effect then additive and antagonism effects with application rates of 0.5 RC and RC, respectively. Generally, the synergistic effect was completely disappeared and the antagonistic effect associated with the increasing application rates of insecticides. As well as, CF varied according to

tested applications RC and different nematode species.

The acceptable combined application between EPNs and insecticides is possible due to tolerance of some EPN species to certain periods of exposure to specific insecticides (Rovesti and Deseo ,1990) besides economizing time and cost.

Table 10. Interactions between steinernematid and heterorhabditid species at a concentration of 200 IJs with three recommended field concentrations (RC) of Indoxacarb against the third and fourth larval instars of *Laseioderma serricorne* Fabricius

Insecticide	Nematode species	The 3rd instar larvae					The 4th instar larvae			
		Application rates (µg a.i/ml)	Observed mortality (%)	CF.	Expected mortality (%)	Interaction	Observed mortality (%)	CF.	Expected mortality (%)	Interaction
Indoxycarb	*S. carpocapsae* (All)	0.25 RC	76.0	-9.31	83.80	Additive	78.0	2.20	76.32	Additive
	S. feltiae (Filipjev)	0.25 RC	72.0	-5.56	76.24	Additive	74.0	5.11	70.40	Additive
	H.bacteriophora (HP88)	0.25 RC	88.0	-4.80	92.44	Additive	90.0	-4.34	94.08	Additive
	H.bacteriophora (Ar-4)	0.25 RC	84.0	-3.49	87.04	Additive	88.0	3.29	85.20	Additive
	H. indica	0.25 RC	70.0	-21.52	89.20	Antagonistic	72.0	11.66	64.48	Additive
	H.bacteriophora (Ba-1)	0.25 RC	68.0	-19.89	84.88	Additive	64.0	1.59	63.00	Additive
	S. carpocapsae (All strain)	0.5 RC	82.0	-9.29	90.40	Additive	88.0	0.18	87.84	Additive
	S. feltiae (Filipjev)	0.5 RC	76.0	-11.55	85.92	Additive	86.0	1.42	84.80	Additive
	H.bacteriophora (HP88)	0.5 RC	92.0	-3.69	95.52	Additive	94.0	-3.05	96.96	Additive
	H.bacteriophora (Ar-4)	0.5 RC	90.0	-2.51	92.32	Additive	88.0	-4.76	92.40	Additive
	H. indica	0.5 RC	74.0	-20.94	93.60	Antagonistic	78.0	-4.60	81.76	Additive
	H.bacteriophora (Ba-1)	0.5 RC	80.0	-12.13	91.04	Additive	84.0	3.70	81.00	Additive
	S. carpocapsae (All strain)	RC	68.0	-29.90	97.00	Antagonistic	62.0	-35.95	96.80	Antagonistic
	S. feltiae (Filipjev)	RC	64.0	-33.05	95.60	Antagonistic	58.0	-39.58	96.00	Antagonistic
	H.bacteriophora (HP88)	RC	74.0	-24.95	98.60	Antagonistic	78.0	-21.37	99.20	Antagonistic
	H.bacteriophora (Ar-4)	RC	72.0	-26.23	97.60	Antagonistic	68.0	-30.61	98.00	Antagonistic
	H. indica	RC	62.0	-36.73	98.00	Antagonistic	66.0	-30.67	95.20	Antagonistic
	H.bacteriophora (Ba-1)	RC	56.0	-42.39	97.20	Antagonistic	48.0	-49.47	95.00	Antagonistic

Various works on compatibility show that insecticides at recommended field concentration showed a negative effect on the viability and infectivity of the EPN. So, the 0.25 RC and 0.5RC can be used together in pest control and all tested products were considered non-toxic to EPNs.

(Koppenhöfer *et al.*, 2002, Koppenhöfer and Fuzy, 2008, Sabino *et al.*, 2014 and El-Ashry and Ramadan, 2021):

In summary, this study demonstrated the potentials of entomopathogenic nematodes and varied application rates of insecticides in controlling of *L.serricorne*. However, further work is necessary to investigate interactions between bio-agents used in control-stored pests, their mechanism of action and possible relationships between toxicity that may initiate because of their use besides, argent need to determine the suitable mode of applications.

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ARABIC SUMMARY

توافق النيماتودا المتطفلة على الحشرية المحلية والمستوردة مع المعاملات المختلفة للمبيدات الحشرية المستخدمة فى مكافحة خنفساء السجائر *Lasioderma serricorne Fabricius*

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تعتبر خنفساء السجائر *Lasioderma serricorne* Fabricius من أهم افات منتجات الحبوب المخزونة والتى تسبب خسائر اقتصادية على مستوى العالم مما يتطلب وضع العديد من الاستراتيجيات لمكافحة لهذه الافة. **قيمت** الدراسة تأثير التركيزات المختلفة لأنواع مختلفة من نيماتودا الحشرات المحلية والمستوردة بمفردها أو مجتمعة مع ثلاث معاملات تطبيق من المبيدات الحشرية (التركيز الموصى به ونصف الموصى به وربع الموصى به) lambda-cyhalothrin ، emamectin benzoate و indoxacarb ضد الأطوار اليرقيه الثالث والرابع لتلك الحشرة تحت ظروف المعمل. **أوضحت النتائج** أن كلا من النيماتودا المحلية *H.bacteriophora* (Ar-4) والمستوردة *H.bacteriophora* (HP88) هما أكثر كفاءة ضد العمر اليرقى الرابع لـ *L. serricorne* عن الطور اليرقى الثالث يليها نيماتودا *S.carpocapsae* (All) بينما كان كلا من النوع *H.bacteriophora* (Ba-1) والنوع *S. feltiae* (Filipjev) أقل الأنواع كفاءة. وتبعا لحسابات LT_{50} وهو التركيز القاتل لـ 50% من الحشرات المختبرة، كان تركيز 100 طور مءعدى/ يرقة هو أفضل تركيز مستخدم ضد يرقات خنفساء السجائر *L. serricorne* . بالأضافة إلى ذلك كان العمر اليرقى الرابع أكثرالأعمار حساسيه لتلك المبيدات الحشرية المختبرة بالمقارنه بالعمر اليرقى الثالث لتك الحشرة المختبرة. علاوة على أن معدل تطبيق ربع الجرعه الموصى بها (0.25) من مبيد إندوكارب كان أكثر سمية فى قتل العمر اليرقى الرابع عند مقارنته بمبيد لمبادا – ثياهالوثرين ومبيد إيماكتين بنزوات لكلا من الطورى اليرقى الثالث والرابع لخنفساء السجائر. ومن ناحية أخرى، أظهرت نتائج توافق خلط الأنواع المحلية والمستوردة من نيماتودا الحشرات مع المبيدات الحشرية المختبرة أختلافات كبيرة والذي يرجع إلى إختلاف معدلات تطبيق المبيدات والتركيزات المستخدمة من النيماتودا الحشريه. **وبذلك يمكن ان نستنتج** إلى أنه تم الحصول على أفضل تأثير متداخل متوافق بينهما كان عند أستخدام معدل تطبيق ربع الجرعه الموصى بها من مبيد لمبادا-ثيهالوثرين مع سلالات النيماتودا الحشرية عند تركيز 100 طور معدى / يرقه والذى أعطى تأثيرًا تنشيطيًا وذلك للتغلب على عدم التوافق خاصة بين الأنواع الغير متجانسة من نيماتودا هيتيرورابتيدى وهذة النتائج يمكن أن تكون مفيدة عند وضع برنامج مكافحة متكاملة لآفات الحبوب المخزونة.