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Bio-Residual Activity of Novel Insecticides in *Spodoptera littoralis* (Boisaduval, 1833) Throughout Its Life Cycle

Seham M. Ismail, Sameh Sh. Hafez, and Sleem Fatma M. A.
Central Agricultural Pesticides Laboratory (CAPL), Agriculture Research Center (ARC)
Dokki, Giza, Egypt
E-mail***** : a25251074@gmail.com

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ABSTRACT

Field foliar residues of five modern insecticides viz, Emamectin benzoate, Indoxicarb, Spinosad, Flubendiamide and *Bacillus thurngiensis* in tomato plants, have been evaluated by feeding larvae of the Lepidopteran *Spodoptera littoralis* (Boisaduval, 1833). Laboratory conditions were selected to study the long-term effects of feeding larvae on the growth and development of *S. littoralis* throughout its life cycle. Residues Spinosad exhibited the highest mortality 87.7 and 83.6%, against 2nd and 4th instars larvae respectively, followed by Flubendiamide and *B. thurngiensis* while residues Emamectin benzoate and Indoxicarb showed the significantly lowest mortality. On the contrary, Emamectin benzoate showed the highest initial kill against 2nd and/or 4th instars larvae, while Spinosad longest residual effect among the tested insecticides. The increased larval duration was observed before pupation with the slowed metamorphosis from larvae to pupae. Treated larvae exhibited lower pupal weights, higher pupal mortality, presence of deformed pupae, and more deformed adults than untreated larvae. All insecticides had a significant effect on the timing of larval development and adult longevity. The development period for males and females was about four days lower than the control for all insecticides tested. Finally, *S. littoralis* adults that resulted from second and fourth instars treated with tested insecticides were affected in their mean cumulative number of eggs laid per female (fecundity), significantly (*P=0.05*) decreased egg fertility, and the sex ratio. Our results suggest that the residues of modern insecticides may have important implications for the population dynamics of the cotton leafworm.

INTRODUCTION

The cotton leafworm, *Spodoptera littoralis* (Lepidoptera: Noctuidae) is a polyphagous insect pest in Egypt and widely worldwide. Larvae of this pest can feed on ~90 economically important plant species belonging to 40 families (Ismail 2020a; Green 2021). Once the larvae stage is attained attacking a wide range of field crops, vegetables and ornamental plants, causing substantial economic damage (Ismail *et al.* 2012). Generally, larvae prefer young leaves and, while they are consuming these, they are also feeding on other parts of the plant. Infestation frequently leads to complete defoliation and devouring of the leaves where the larvae interfere with plant development by destroying growth points. The losses due to feeding ranging from 35 to 100% are possible in the field caused by larvae and their habits (EPPO 2015). In addition, the high reproductive capacity and migration over large distances in the adult stage, its populations can expand rapidly and move across fields quickly, therefore, necessitates special efforts to control this pest (Xu *et al.* 2015). At present, chemical insecticides are still the main effective method to control *S. littoralis* in Egypt and many countries but the control achieved is not successful because of the insect's high capacity to develop resistance toward the majority of conventional insecticides (Hilliou *et al.* 2021). Therefore, this pest became a major concern for cotton producers, and economic field crops, there is a need for alternatives and measures for the control of *S. littoralis* and crop protection (Mushtaq *et al.,* 2021). Scientists and growers are seeking alternative materials that are effective against this pest, the use of active principles with different modes of action is suggested as a tool of phytosanitary protection (Mushtaq *et al.,* 2021), in order to avoid the occurrence of problems related to the resistance of insect pests (Umetsu and Shirai 2020). The alternative control tactics that show promise as a potential tool in *S. littoralis* resistant management programs and prevention of economic losses of crops is the use of the most effective insecticides such as novel insecticides with different categories that have a wide array of unique modes of action and have selectivity to target insects, they represent an existing opportunity for the effective control of cotton leafworm (Ismail *et al.,* 2020; Umetsu and Shirai 2020). The objective of this study is to determine the toxicity of field foliar residues of five commercial insecticides viz, Emamectin benzoate, Indoxicarb, Flubendiamide, Spinosad and *B. thurngiensis* representing the main active ingredients belonging groups to Avermectins, Oxadiazines, Phthalic acid diamide and bioinsecticide respectively, applied to tomato plants, *Lycopersicon esculentum* L., under field conditions; as well as its effects on development and fecundity by second and fourth instars of *S. littoralis*. This work provides a better understanding of the impact of several modern insecticides that are mainly applied as foliar sprays in tomato crops and are used against pests.

MATERIALS AND METHODS

Rearing *S. littoralis* in Laboratory Conditions:

Spodoptera littoralis were obtained from a colony maintained in the Insect Population Toxicology Department, Central Agricultural Pesticides Laboratory, Agriculture Research Center, Dokki, Giza, Egypt. Larvae were reared on leaves of castor bean (*Ricinus communis* L.) replaced periodically.

Insecticides Application and Sampling:

Field trials were performed in the 2020 season at Etay El-Baroud Agriculture Research Station, El-Behera Governorate Egypt, to evaluate the efficiency and residual effects of five insecticides against the 2nd and 4th instars larvae of *S. littoralis*. The trials were planted with the tomato 'Miller', *L. esculentum* L., var. Beto 86 in three plots each plot area was 42 m^2 separated by untreated plots as a check (42 m^2) to prevent cross-contamination was sprayed with water only. The treatment plots were spotted in a complete randomized block design (RCBD), irrigation and fertilization were made according to the crop schedule. Normal agricultural practices were followed with the application of the field rate of five commercial insecticides by the Egyptian Ministry of Agriculture, 100 cm/100 liters of water, 60 gm/feddan, 30 cm/100 liters of water, 200 gm/feddan and 100 gm/feddan for Indoxicarb (Zinad® SC 15%); Emamectin benzoate (Emaset® SG 5%); Spinosad (Pakgro® SC 48%); *B. thurngiensis* var. *kurstaki* (Dipel® DF 6.4%); Flubendiamide (Tacomy® WDG 20%) respectively. Insecticides were applied on the 18th July 2020 using a single nozzle knapsack sprayer (20 liters). About one hour after application (zero time), leaves instantly of every plot were collected randomly and put in paper bags then transferred to the laboratory for bioassay tests.

Residual Activity:

Newly molted (<6 h old) second and fourth instars of *S. littoralis* were starved for 4 h before bioassay to induce a higher feeding rate. Untreated tomato leaves were provided to controls. Larvae were placed in glass jars (250 ml) covered with muslin containing treated tomato leaves to feed for 24 h. The bioassay was performed three times with thirty larvae per insecticide used. Larval mortality was scored after 1-, 3- and 5-days' exposure to each insecticide to determine initial and residual effects; if no movement was observed, larvae were considered dead.

Biological Parameters of *S. littoralis* Feeding on Tomato Leaves Treated with Insecticides:

Development of surviving second and fourth instars of *S. littoralis* was individually per insecticide was followed and larval, pupal and adult durations, pupal weight, percent pupation, and adult emergence were recorded. The deranged metamorphosis, morphogenesis was detected and percent malformations in pupae or adults were calculated.

Adult males and females of *S. littoralis* treated second and fourth instars were sexed, and pairs (made up of one ♂ and one ♀) were placed in plastic petri dishes (9 cm in diameter by 2.5 cm in height) covered inside with filter paper on which females laid their eggs. Moths were provided with a 10% solution. Evaluations took place twice a day at 12-h intervals until oviposition started; the eggs deposited on the filter paper were collected at intervals of 1, 2, and 3 d. Fecundity was determined daily was calculated as follows:

$$Fecundity = \frac{A}{B}$$

Where:
A = Number of laid eggs per ♀,
B = Reproductive lifetime (in days).

Eggs were collected and placed in glass containers until the eggs hatched to determine the fertility percentage. At the end of the experiment, the sterility index was calculated as follows:

$$Sterility\ index\ = [100 - \left(\frac{AB}{CD}\right) x100]$$

Where:
A = Number of eggs laid per female in the treatment,
B = Percentage of hatching in the treatment,
C = Number of eggs laid per female in the control,
D = Percentage of hatching in the control.

Statistical Analysis:

Data of the residues of Emamectin benzoate, Indoxicarb, Flubendiamide, Spinosad and *B. thurngiensis* var. *kurstaki* on biological parameters of *S. littoralis* were statistically performed using one-way ANOVA using SAS software. Mean values were analyzed with Tukey's test at the 0.05 level of probability and compared with the control.

RESULTS

Residue Activity:

Results show that the initial effect (at zero time after spray), Emamectin benzoate proved to be the most effective were caused at 100% for 2nd and 97.0% for 4th instar larvae while *B. thurngiensi* was the least effective at 33.5 and 28.1% for 2nd and 4th instars larvae respectively (Table 1). Based on the general mean of residual activity of compounds, Spinosad was a superior compound giving 86.75 and 81.6% for 2nd and 4th instars larvae respectively, followed by Flubendiamide and *B. thurngiensi* whereas, Indoxicarb was the least effective.

Table 1. Initial and residual effects of five modern insecticides at field rate against second and fourth instars larvae of *Spodoptera littoralis*.

Treatment	**Field application rate**	**Initial effect % at *zero time**		**Residual effects**				**Mean of residual effect %**	
				3 days		**5 days**			
		2nd	4th	2nd	4th	2nd	4th	2nd	4th
Spinosad	30	49.1	42.6	94.9	89.5	78.6	73.6	86.75	81.6
Indoxicarb	100	95.8	92.0	55.5	45.5	13.0	11.7	34.25	28.6
Flubendiamide	100	40.6	33.1	83.3	79.7	68.4	62.5	75.85	71.1
Emamectin benzoate	60	100	97.0	60.0	54.8	35.3	29.5	47.65	42.15
Bacillus thurngiensis	200	33.5	28.1	73.7	69.7	59.1	55.6	66.4	62.65

*Zero time = one hour after application of insecticides.

Bioassays of Residual Activity:

The results of the larval duration starting from initial instars treated up to pupation and adult longevity were recorded (Table 2). The obtained results showed an insignificant increase in the case of pretreated 2nd instar which ranged from 16.8, 15.7, 15.0, 14.8 and 14.5 days for Emamectin benzoate, Indoxicarb, Spinosad, Flubendiamide and *B. thurngiensis*, compared with 14.3 days for control. While there was significant prolongation in larval duration for the pretreated 4th instar ranged between 10.77 and 13.68 days as compared with 10.35 days for control. All insecticides showed a highly significant decrease in pupal duration in both 2nd and 4th instars. On the other hand, the treatments had a low different effect on adult longevity compared to control both males' and females' adult longevity were reduced with all the tested insecticides especially the males which were more affected as a result of both pretreated 2nd and 4th instars to record 8.25, 9.00 and 9.33 days and significant reduction of 8.87, 9.13 and 10.33 days by Spinosad, Flubendiamide and *B. thurngiensis* respectively. While insignificant reduction was recorded in females' longevity as a result of pretreated 2nd and 4th instar ranged 12.69 and 12.81 days, respectively, especially with Indoxicarb.

Table 2. Effect of five modern insecticides at field rate on duration (days) of the second and fourth larval, pupal and adult stages of *Spodoptera littoralis*.

Treatment	**Field application rate**	**Larval duration**		**Pupal duration**		**Adult longevity**			
						2nd		**4th**	
		2nd	**4th**	**2nd**	**4th**	♂	♀	♂	♀
Spinosad	30	15.0^{b} ±0.33	12.00^{c} ±0.47	9.71^{c} ±0.10	10.22^{c} ±0.26	8.25^{d} ±0.42	10.66^{cd} ±0.50	8.87^{cd} ±0.42	11.87^{bc} ±0.50
Indoxicarb	100	15.7^{bc} ±0.20	12.89^{c} ±0.23	9.03^{c} ±0.19.	9.78^{cd} ±0.53	11.00^{a} ±0.58	12.69^{ab} ±0.28	11.65^{a} ±0.58	12.81^{ab} ±0.28
Flubendiamide	100	14.8^{ab} ±0.60	11.33^{b} ±0.20	11.50^{ab} ±0.30	11.65^{ab} ±0.18	9.00^{c} ±0.22	10.91^{cd} ±0.33	9.13^{c} ±0.22	12.53^{ab} ±0.33
Emamectin benzoate	60	16.8^{c} ±0.70	13.68^{d} ±0.32	8.11^{d} ±0.68	8.60^{e} ±0.41	10.19^{b} ±0.39	11.88^{bc} ±0.22	10.89^{ab} ±0.39	12.26^{c} ±0.22
Bacillus thurngiensis	200	14.5^{ab} ±0.28	10.77^{a} ±0.65	11.88^{ab} ±0.90	12.00^{a} ±0.20	9.33^{c} ±0.65	11.57^{bc} ±0.85	10.33^{b} ±0.65	12.98^{ab} ±0.85
Control		14.3^{a} ±0.10	10.35^{a} ±0.85	12.28^{a} ±0.60	12.28^{a} ±0.60	11.90^{a} ±0.40	13.03^{a} ±0.21	11.90^{a} ±0.40	13.03^{a} ±0.21

Means within the same column followed by a common letter do not differ significantly at $P = 0.05$. Data are averages of 3 replicates of 10 larvae each, mean ± SE.

Data presented in Table (3) showed that the induced a highly significant decrease of the pupation percentage with respect to control were 65.86 and 61.1 % for 2nd and 4th instars larvae treated with Spinosad, respectively, as compared to 97.0% pupation of control. Whereas, the larval feeding on tomato leaves treated with Indoxicarb caused a non-significant decrease in the pupation (90.3%). All insecticides highly significantly reduced the pupal weight, Spinosad was the most suppressive one on the pupal. Moths emergence reduce significantly in all insecticides compared to control.

Results illustrated in Table (3) showed that the tested insecticides caused formations with various degrees for pupae and adults resulting from feeding either 2nd or 4th instars larvae of *S. littoralis* on tomato leaves treated with the field rate of each insecticide. Malformations were recorded based on the external morphology the highest percentage of deformation exist in pupa intermediate and were recorded (14.5 and 12.7%) for Emamectin benzoate in pretreated 2nd and 4th instars, respectively followed by Indoxicarb (6.6 and 4.6% respectively) and recorded the lowest value in pretreated 2nd and 4th instars with *B. thurngiensis* (1.3 and 1.1% respectively) as compared with zero % malformation for control. All insecticides caused various degrees of malformations in adults the males showed a higher effect than females. Pretreated 2nd instar with for Emamectin benzoate recorded the highest males' malformation (7.7%) followed by for Indoxicarb (5.0%), while the lowest value of males' malformation was by *B. thurngiensis* on the pretreated 4th instar. The females' moth recoded malformation in the range of (3.1 to 6.9%) for Emamectin benzoate and Indoxicarb for 2nd and 4th instars, respectively. The malformation during generation recorded its maximum value in 2nd instar larvae than 4th instar larvae as compared with control which didn't show any larval deformations.

Table 3. Effect of five modern insecticides at field rate on pupal and adult stages of the second and fourth instars larval of *Spodoptera littoralis*.

Treatment	Field application rate	Pupal stage						Adult stage					
		Pupation (%)		Weight (mg)		Malformation (%)		Emergence (%)		Malformation (%)			
										2nd		4th	
		2nd	4th	2nd	4th	2nd	4th	2nd	4th	♂	♀	♂	♀
Spinosad	30	61.1d ±3.2	65.8d ±2.2	239e ±3.4	242e ±3.4	4.4c ±0.5	3.4c ±0.3	89.4a ±1.11	92.0a ±1.97	4.2c ±0.8	3.5c ±0.5	2.0b ±0.6	1.3a ±0.13
Indoxicarb	100	90.3a ±1.0	88.9ab ±5.7	261c ±3.8	280c ±2.8	6.6d ±0.2	4.6d ±0.9	79.0b ±1.65	82.6b ±1.45	5.0d ±0.45	4.4d ±0.93	3.9c ±0.5	3.1b ±0.25
Flubendiamide	100	74.4c ±5.8	77.3c ±3.6	247d ±5.6	259d ±5.1	2.6b ±0.6	2.0b ±0.3	68.3c ±1.83	71.3c ±1.77	3.3ab ±0.3	2.0a ±0.3	1.4a ±0.11	1.1a ±0.1
Emamectin benzoate	60	85.4b ±1.0	82.4b ±6.6	242d ±2.9	253d ±4.1	14.5e ±0.5	12.7e ±0.9	74.1b ±1.13	76.4c ±1.13	7.7e ±0.57	6.0e ±0.26	5.3d ±0.7	4.2c ±0.7
Bacillus thurngiensis	200	66.3d ±3.2	69.5cd ±4.7	273b ±6.1	299b ±3.4	1.3a ±0.7	1.1a ±0.1	90.8a ±1.00	93.3a ±1.57	2.8a ±0.7	1.6a ±0.2	1.0a ±0.90	1.0a ±0.2
Control		97.0a ±1.1	97.0a ±1.1	340a ±5.4	340a ±5.4			96.7a ±1.47	96.7a ±1.47				

Means within the same column followed by a common letter do not differ significantly at $P = 0.05$. Data are averages of 3 replicates of 10 larvae each, mean ± SE.

Table (4) represents the effect of insecticides on adult fecundity, fertility and sex ratio. It is clear that all insecticides affect the sex ratio by producing males more than females (about 2 folds), the most effective insecticide was Spinosad which affected both pretreated 2nd and 4th instars (1.77:1) and (1.50:1), respectively followed by Flubendiamide (1.14:1 and 1.12:1 respectively) compare with control (0.80:1). The oviposition was extensively inhibited after treated 2nd instar larvae to 608.2, 661.34, 907.05, 1155.3 and 1188.1 egg/female for Spinosad, Flubendiamide, *B. thurngiensis*, Emamectin benzoate, Indoxicarb treatments respectively while after treated 4th instar larvae gave 611.2, 675.14, 1021.65 and 1148.75 egg/female, respectively compared with 1283.7 egg/female for control. Fertility was significantly decreased in all insecticides treatments, compared to 94.0% in control. Percentage of sterility was recorded as the highest (73.5 and 49.4%) for Spinosad in pretreated 2nd and 4th instars, respectively followed by Flubendiamide and *B. thurngiensis* while recorded the lowest value in pretreated 2nd and 4th instars with Emamectin benzoate followed by Indoxicarb.

Table 4. Effect of five modern insecticides at field rate on fecundity, fertility and sterility of the second and fourth instars larval of *Spodoptera littoralis*.

Treatment	Field application rate	Sex ratio		Fecundity (eggs/female)		Fertility (egg hatchability %)		Sterility (%)	
		2nd	4th						
		♂ : ♀	♂ : ♀	2nd	4th	2nd	4th	2nd	4th
Spinosad	30	1.77 : 1.0	1.50 : 1.0	608.2^{e}±4.3	611.2^{e}±2.36	50.0^{d}±1.50	60.2^{c}±1.77	73.5^{c}±1.77	49.4^{c}±1.13
Indoxicarb	100	1.14 : 1.0	1.12 : 1.0	1188.1^{b}±4.54	1148.75^{b}±3.70	74.3^{b}±2.36	78.4^{b}±2.83	53.8^{a}±1.92	25.5^{a}±2.11
Flubendiamide	100	1.41 : 1.0	1,36 : 1.0	661.34^{e}±2.4	675.14^{e}±5.7	55.8^{cd}±1.74	64.1^{c}±1.12	71.8^{c}±3.85	48.8^{c}±1.21
Emamectin benzoate	60	1.17 : 1.0	1.16 : 1.0	1155.3^{c}±4.71	1118.30^{c}±4.83	68.6^{bc}±1.41	70.7^{b}±2.15	61.6^{b}±1.92	29.6^{ab}±3.78
Bacillus thurngiensis	200	1.24 : 1.0	1.22 : 1.0	907.05^{d}±4.9	1021.65^{d}±5.19	60.6^{c}±1.67	66.2^{c}±1.13	63.6^{b}±1.40	31.1^{b}±1.83
Control		0.80 : 1.0	0.80 : 1.0	1283.7^{a}±7.07	1283.7^{a}±7.07	94.0^{a}±3.7	94.0^{a}±3.7		

Means within the same column followed by a common letter do not differ significantly at $P = 0.05$. Data are averages of 3 replicates of 10 larvae each, mean ± SE.

DISCUSSION

Depending on the currently available literature, very few studies have examined the residual effects of modern insecticides on subsequent stages of insects. For example, Emamectin benzoate, Indoxicarb, Spinosad, Flubendiamide and *B. thurngiensis*, among modern insecticides exhibited high efficacy in controlling Lepidopterous insect pests (Umetsu and Shirai 2020). In the present study, the second and fourth instars larval of *S. littoralis* were exposed to these insecticides at field dose. Based on the initial effect (at zero time after spry), Emamectin benzoate proved to be the most effective causing 100% for 2nd and 97.0% for 4th instar larvae while *B. thurngiensi* was the least effective at 33.5 and 28.1% respectively. Results are in close agreement with the results obtained by Ismail (2021) showed that the mortality of *Agrotis ipsilon* (Hüfnagel) feeding on the cotton plant after direct application of Emamectin benzoate was recorded (100%), and reported that the Emamectin benzoate was significantly superior residual activity than Chlorantraniliprole and Indoxicarb. Unlike Spinosad, *B. thurngiensis* and Flubendiamide had a strong lethal effect on *S. littoralis* after five days, these results showed that the strong toxicity depends on the developmental stages and exposures. Similar results were observed with other insects that were obtained by Yadav *et al.* (2017) who reported that the mortality increased in diamondback moth (*Plutella xylostella* Linn.), *Spodoptera exigua* (Hübner) Wang *et al.* (2013) or *Spodoptera littoralis (*Boisad.) Ismail (2020b) feeding on cabbage, tomato or cotton leaves treated with Spinosad after application 29, 14 and 12 days respectively. Other invertebrates Ismail and Morshedy (2013); da Costa *et al.* (2020) showed that *Spodoptera frugiperda* or *S. littoralis* are sensitive to residues *B. thuringiensis* after 3 to 7 days from feeding on treated leaves. Also, in concordance with our results, Flubendiamide had no direct toxicity on second and fourth instars larvae of S. *littoralis* when fed with treated leaves these results agree with Tohnishi et al. (2005); Gentz *et al.* (2010); Wanumen et al. (2016) reported that Flubendiamide is a synthetic diamide insecticide that caused a high activity after a long time against Lepidoptera. On contrary, residues of Indoxicarb were the least effective of *S. littoralis* this results in agreement with Gupta *et al*. (2019) revealed that the shortest persistence period of Indoxacarb residues on okra (1–3 days), on tomato (Sharma *et al.*, 2018), and the mortality decreased in earthworms and arthropods (Sakthiselvia *et al.*, 2020).

Residues of insecticides may cause biological effects, so studying life-history traits is essential **(**de Araujo and Busoli 2020) therefore, surviving larvae were maintained until the end of their development to study the effects of tested insecticides residues on the biological fitness of *S. littoralis*. In this study, all insecticides increased the duration of larval instars and slowed metamorphosis from larvae to pupae. We also found that suppression of pupal weight gain is directly related to the mode of action of these insecticides. Additionally, all insecticides caused deformations with various degrees for pupae and adults resulting from the treated 2nd and 4th instars larvae. Previous studies showed that modern insecticides had a significant disruptive effect on both larval duration and pupal weight of Lepidoptera pests (Ismail and Shaker 2013; Moadelil *et al.*, 2014; Dagar *et al.*, 2020; Sukirno *et al.*, 2021).

Fecundity and fertility were significantly reduced by tested insecticides. Based on the species of insecticide; Spinosad, Flubendiamide and *B. thurngiensis* are more effective for *S. littoralis*. than Emamectin benzoate and Indoxicarb. Higher negative effects on fecundity and survivorship in Spinosad showed 46.8 and 35.9% reduction in eggs number on both pretreated 2nd and 4th instars respectively, followed by Flubendiamide (40.6 and 31.8% respectively), and *B. thurngiensis* (35.5 and 29.5% respectively) while Emamectin benzoate (27.0 and 24.7 respectively) and Indoxicarb was least effect 20.9 and 16.5 respectively, (P = 0.05), leading to the conclusion that these insecticides have a noticeable negative effect on the *S. littoralis*, it is important to point out that female's deterrence effects can differ with the insecticide, and the age larva stage tested. Results showed that Spinosad, Flubendiamide and *B. thurngiensis* had a slow rate of penetration in the first one h after application; however, once present inside the *S. littoralis* larvae, the insecticide is not readily metabolized, thereby contributing to its high level of biological activity, which may reflect the fact that reproduction, offspring production, and survival was affected by insecticides. A significant adverse effect of bioinsecticides on the longevity of *S. littoralis* larvae and adults has been reported by Ismail and Shaker (2013). Similar to our laboratory results in other insects of different orders reported that fecundity and fertility of *Chrysodeixis includens* (Lepidoptera: Noctuidae) Rodrigues *et al.* (2018) *Spodoptera frugiperda* (Lepidoptera: Noctuidae) Gao *et al.* (2021) *Spodoptera litura* Fab. (Lepidoptera: Noctuidae) dos Santos *et al.* (2021); Sukirno *et al.* (2021) and *Agrotis ipsilon* (Hüfnagel) Ismail (2021) were significantly reduced in bioinsecticides-treated groups. According to the obtained results, these insecticides may provide up to 80% control of *S. littoralis*, therefore can serve as a practical tool for contributing to its controlling the growth of S. *littoralis* populations.

Conclusion

Based on this study, Emamectin benzoate, Indoxicarb, Spinosad, Flubendiamide and *Bacillus thurngiensis* exhibited negatively affected the development and reproductive parameters against *Spodoptera littoralis*. Therefore, it can be recommended to use these insecticides as an effective agent in the integrated pest management of this dangerous pest.

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ARABIC SUMMARY

تقييم النشاط الحيوي المتبقي للمبيدات الحشرية الجديدة تجاه دورة حياه دودة ورق القطن

سهام منصور إسماعيل– سامح شعبان حافظ – فاطمه محمد أمين سليم
المعمل المركزي للمبيدات - مركزالبحوث الزراعية - الدقي - الجيزه – مصر

أجرى هذا البحث لتقييم فعاليه متبقيات خمسة مبيدات حشرية حديثة وهي الإيماميكتين بنزوات، اندوكسيكارب، إسبينوساد، فلوبندياميد، باسيللس ثيورنجينسس تجاه الأطوار المختلفه لدودة ورق القطن وذلك بأستخدام التقدير الحيوي عن طريق تغذية يرقات العمر الثاني والرابع على أورق نبات الطماطم التي سبق رشها بالجرعه الموصى بها من هذه المبيدات. أظهرت متبقيات مركب إسبينوساد أعلى معدل وفيات 87.7 و 83.6٪ مقابل يرقات الطورين الثاني والرابع على التوالي، يليه مركب فلوبندياميد ثم باسيللس ثيورنجينسس بينما أظهرت متبقيات مركب الإيماميكتين بنزوات و اندوكسيكارب أقل معدل نفوق. على العكس من ذلك كان مركب الإيمامكتين بنزوات أعلى المركبات فى التأثير الأولي ومركب إسبينوساد في التأثير المتبقي بين المبيدات التي تم اختبارها ضد يرقات الطور الثاني والرابع. أشارت النتائج زيادة مدة اليرقات قبل التشرنق مع تباطؤ التحول من اليرقات إلى العذارى كما لوحظ أوزاناً أقل ونفوقاً أعلى للعذارى مع وجود شرانق وحشرات كاملة مشوهة ناتجه عن اليرقات المعالجة كما أن جميع المبيدات المختبرة أدت إلى خفض عمر الفراشات (الذكور والأناث) بنحو أربعة أيام أقل من الكنترول. أخيرًا، تأثر البالغين لدودة ورق القطن الناتجة عن العمر الثاني والرابع المعالج بالمبيدات الحشرية المختبرة في متوسط العدد التراكمي للبيض الذي تم وضعه لكل أنثى (الخصوبة) ، مما أدى إلى انخفاض معنوي في خصوبة الأناث، ونسبة الجنس. تشير نتائجنا إلى أن متبقيات المبيدات الحشرية الحديثة قد يكون لها آثار مهمة على الديناميكيات السكانية لدودة ورق القطن.