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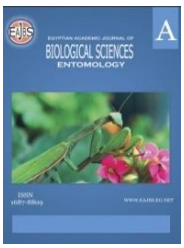

Effectiveness of Teflubenzuron, Emamectin benzoate, and Alfa-cypermethrin on Fall Armyworm, *Spodoptera frugiperda* (J.E Smith) (Noctuidae: Lepidoptera), under Laboratory and Field Conditions

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ABSTRACT

Fall armyworm, *Spodoptera frugiperda* (J.E Smith) (Noctuidae: Lepidoptera) has become a serious pest in maize. In our study, we evaluate the efficacy of Teflubenzuron (Nomolt® 15% EC), Emamectin benzoate (Proclaim® 5% SG) and Alfa-cypermethrin (Fastac® 5% EC) on the fourth instar larvae of the fall armyworm (FAW), *Spodoptera frugiperda* (J.E Smith) (Lepidoptera: Noctuidae) both laboratory and field experiments. The results revealed that the LC_{50} values obtained were 0.18 ppm, 0.019 mg/ml, and 0.6046 mg/ml for *S. frugiperda* larvae treated with different concentrations of Teflubenzuron, Emamectin benzoate and α-cypermethrin respectively. The study, investigates the prolongation of larval duration, decreasing both pupation % and pupal duration. Field application of Teflubenzuron, Emamectin benzoate and α-cypermethrin against the fall armyworm (FAW), *Spodoptera frugiperda* was expressed as a percentage reduction of larval population and residual toxicity. Conclusion of our study that the insecticide Teflubenzuron, Emamectin benzoate and α-cypermethrin were efficient and can be recommended to control the fall armyworm (FAW), *S. frugiperda*.

INTRODUCTION

Fall armyworm (FAW), *Spodoptera frugiperda* (J.E Smith) (Lepidoptera: Noctuidae) is a destructive insect pest and is now a significant global threat to agricultural productivity. The fall armyworm causes damage to different cultivated crops, maize, rice, sorghum, sugarcane, cabbage, beet, groundnut, soybean, alfalfa, onion, pasture grasses, millet, tomato, potato, and cotton (Day *et al*. 2017). *Spodoptera frugiperda* feed on both vegetative and reproductive parts of the host plant, which causes yield reductions. The larvae instars start feeding nearby to the ground then cause holes in leaves and consume from the edge to inward. The population densities of larval reduce to half because of the behavior of cannibalistic.

Maize (*Zea mays L.*) is one of the important cereals called the "Queen of cereals" as well as a commercial crop in Egypt. This crop is used as food, fodder, fuel, and poultry feed and its cultivation is easy. The recent invasion of the fall armyworm, *Spodoptera frugiperda* (Noctuidae: Lepidoptera) has a great threat to maize cultivation and causes damage.

Insect growth regulators (IGR) have high activity and selectivity against insects with inherently low toxicity to non-target wildlife. As a result of their mode of action, those have a greater effect on immature stages than on adults of insect species. Most of the IGR have a unique mode of action that disrupts the molting process or cuticle formation in insects or interferes with the hormonal balance of insects. They are characteristically slow with acting against a narrow range of sensitive stages of the insects' life cycle and harmful effects against target pests. Teflubenzuron is a chitin synthesis inhibitor highly effective in controlling lepidopteran pests, including nowadays the world widely distributed fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith, 1797) (Lepidoptera: Noctuidae). Emamectin benzoate is a member of the avermectin family, which is a class of natural fermentation products of the soil microorganism, *Streptomyces avermitilis* (Stavrakaki *et al.* 2022). Emamectin benzoate is a high effect on the neuromuscular junction, causing paralysis and finally death (Ishaaya *et al.* 2002). Pyrethroids damage hemolymph and interfere with the insect's central nervous system, causing muscle spasms and paralysis that leads to an inability to function or eat so death.

This study, therefore, was initiated to evaluate the susceptibility of fourth instar larvae of the fall armyworm (FAW), *S. frugiperda* to Teflubenzuron, Emamectin benzoate and α-cypermethrin, under both laboratory and field experiments.

MATERIALS AND METHODS

Insect Rearing:

In the laboratory, the culture of the fall armyworms, *Spodoptera frugiperda* from the division of the Cotton Leaf Worm, Plant Protection Research Institute Agriculture Research Center. They were incubated under constant conditions at 25 ± 1 °C, 60% ± 5% (RH) and a 14:10-h light: dark. The larvae were reared on fresh castor leaves (Ricinus communis) and larvae were reared individually to avoid cannibalism in small cups (7.0 cm in diameter, 3.5 cm in height) with sawdust to reduce moisture He *et al*., (2019), until pupation and moths were transferred to glass jars (5L), fed on 10% sucrose solution Kandil *et al.*, (2020).

Tested Compound:

Nomolt® 15% EC:Active ingredients: Teflubenzuron (IUPAC: 1-(3,5-dichloro- 2,4-difluorophenyl)-3-(2,6- difluorobenzoyl urea).

Proclaim® 5% SG: Active ingredients: Emamectin benzoate (4"-epi-methylamino-4"-deoxyavermectin B1)

Fastac® 5% EC:Active ingredients: α-cypermethrin ((RS)-alpha-cyano-3-phenoxybenzyl (IRS)-cis, trans-3-(2,2-dichloroviny1-2,2 dimethylcyclopro-panecarboxylate)

Bioassay Tests and Calculate LC_{50} under Laboratory Conditions:

To evaluate the toxicity of Teflubenzuron, Emamectin benzoate and α-Cypermethrin, treatment of the fourth instar larvae of *Spodoptera frugiperda* with different concentrations of them under laboratory conditions. Treated castor bean leaves by dipping in different concentrations of the tested compounds for 48 hrs, which was modified from the method described by (Mokbel and Huesien 2020). Prepared five different concentrations of Teflubenzuron, Emamectin benzoate and α-Cypermethrin. One hundred larvae were divided into four replicates; every 25 larvae were used for each concentration. Control treated castor bean leaves by dipping them in distilled water. Record the mortality percentage every day, mortality was corrected with the corresponding mortality in the untreated check according to Abbott's formula (Abbott, 1925). Calculate of LC_{50} value by the probit- analysis method of (Finney, 1971).

Sublethal Effects of Bioinsecticides on the Development of *Spodoptera frugiperda*:

Newly moulted 4th instars larvae of *Spodoptera frugiperda* treated with LC_{50} value of Teflubenzuron, Emamectin benzoate and α-Cypermethrin. Three replicates, with 50 larvae each, were prepared. Refresh castor bean leaves for surviving larvae, to record larval duration, pupal duration, pupation% and adult emergence %.

Field Experiments:

Effectiveness of Teflubenzuron, Emamectin benzoate and α-Cypermethrin Treatments 0f The Fall Armyworm, *Spodoptera frugiperda* under Field Conditions:

Two field experiments were carried out in Kaha research station, Plant Protection Research Institute (PPRI), Kaha district, Qualubia Governorate and in Sanores district, Fayoum Governorate.

The experiment area was 8 kerate divided into 16 plots, the area divided into three completely randomized blocks. The tested compound was carried out as follows:

1-Nomolt® 15 % EC: (Teflubenzuron) at the rate of 200 g/litre, as a recommended rate.

2-Proclaim® 5%SG: (Emamectin benzoate) at the rate of 60 g/ litre, as a recommended rate.

3-Fastac® 5% EC: (α-Cypermethrin) at the rate of 100 g/litre, as a recommended rate.

Calculation of Reduction Rate:

Data from field experiments were taken before application and collection of sampling continuous up to 10 days post-treatment and registered in specific tables**.** The percentage of reduction in the population density of insects was estimated according to **Henderson and Tilton (1955)**.

Reduction rate =1-C_1/C_2 x T_2/T_1 x 100

Where:

C_1: Population in control before application.

C_2: Population in control after application.

T_1: Population in treatment before application.

T_2: Population in treatment after application.

Statistical Analysis Procedure:

The significance of the main effects was determined by using analysis of variance (ANOVA). The significance of various treatments was evaluated by Duncan's multiple-range tests ($p<0.05$).

RESULTS AND DISCUSSION

1-Toxicological Studies Under Laboratory Conditions:

The efficiency of Teflubenzuron, Emamectin benzoate and α-Cypermethrin on 4th instar larvae of *S. frugiperda* in Table (1). The LC_{50}, as well as regression lines, were calculated, and the LC_{50} values recorded 0.18 ppm, 0.019 mg/ml, and 0.6046 mg/ml for Teflubenzuron, Emamectin benzoate and α-cypermethrin respectively. Also, the slope values were 1.561, 1.553, and 1.673 for Teflubenzuron, Emamectin benzoate and α-cypermethrin respectively, showing the homogeneity of the larvae. These results agree with Karina da Silva *et al.* (2020) who evaluate larval mortality in two *S. frugiperda* populations submitted to different insecticides (teflubenzuron), and they found that the insecticides teflubenzuron and flubendiamide presented the highest mortality levels of *S. frugiperda.* Also agree with Zhuo-Kun Liu *et al.* (2022) who studied the toxicity of Emamectin benzoate on *S. frugiperda* and found a low dose of sublethal concentrations of Emamectin benzoate could significantly influence the life cycle of *S. frugiperda* parental and I offspring I generation I. Also agreed with Eman A. Fouad *et al.* (2022) showed that the laboratory strain cotton leafworm, is overly sensitive to Emamectin benzoate (LC_{50}= 0.001 ppm) and alpha-cypermethrin (LC_{50}= 13.95 ppm) exhibited low toxicity to the laboratory

strain of *S. littoralis*.

Table 1: Toxicity values of Teflubenzuron, Emamectin benzoate and α-cypermethrin against 4th instars *Spodoptera frugiperda* larvae.

Treated compound	LC_{50}	Confidential limits for (95%) LC_{50}		Slope±S.E.
		Lower	Upper	
Teflubenzuron	0.18 ppm	0.1031	0.2680	1.561±0.31
Emamectin benzoate	0.019 mg/ml	0.011	0.1203	1.553±0.218
α-cypermethrin	0.6046 mg/ml	0.4214	0.9831	1.673±0.126

2-Bioassay Tests under Laboratory Conditions:

The sublethal concentration (LC_{50}) of Teflubenzuron, Emamectin benzoate and α-cypermethrin was evaluated their virulence on fourth instars *S. frugiperda* larvae in Table (2). The data in Table (2) indicated that LC_{50} of all treated compounds resulted in a prolongation of the larval and pupal duration compared to the control. On the contrary, Pupation percentage rates recorded 62.7, 48.9, and 59.3% for Teflubenzuron, Emamectin benzoate and α-cypermethrin respectively, compared to 94.6% for control, which was significantly decreased. The reduction percentage in adult emergence was 72.4, 65.8, and 70.3% for Teflubenzuron, Emamectin benzoate and α-cypermethrin respectively, compared to 96.2% for control. The data obtained agree with the data of Antonio *et al.* (2022), Chitin synthesis inhibitors are low non-target effects, so they are used in pest control and are an excellent choice for integrated pest management programs. Teflubenzuron is a chitin synthesis inhibitor used to control fall armyworm, *Spodoptera frugiperda* (J.E. Smith, 1797) (Lepidoptera: Noctuidae). Also agree with Hanan (2022) who used the sublethal dose of teflubenzuron to control *Plutella xylostella L*. (Lepidoptera: Plutellidae) and investigation that low larval survival rate, longer larval and pupae duration, and longer development time, compared with the unselected strain. Our results agree with Zhuo-Kun Liu *et al.,* (2022) who studied the effect of Emamectin benzoate on *S. frugiperda* and found the sublethal concentration (LC_{20}) of Emamectin benzoate significantly prolonged the pupal period of males but not of female and reduced the development time of offspring larvae. Also, Mokbel and Huesien (2020) found that the Emamectin benzoate sublethal concentrations (LC_5 and LC_{15}) increased the larval period of *S. littoralis*. Agreed also with Sileshi *et al*., (2022) who determined of the most effective insecticide against maize fall armyworm, *Spodoptera frugiperda*, found the highest number of larval mortalities was recorded on the treatment plot treated with Alpha-Cypermethrin (40%) at day one after insecticide application.

Table 2: Biological aspects of *Spodoptera frugiperda* treated as 4th instar larvae with LC_{50} of Teflubenzuron, Emamectin benzoate and α-Cypermethrin.

Treated compound	Mean larval duration (days ± S.E.)	Mean pupal duration (days ± S.E.)	Pupation (%)	Adult Emergence (%)
Teflubenzuron	19.6^{b} ±0.35	11.7^{b} ±0.41	62.7	72.4
Emamectin benzoate	21.9^{c} ±0.53	13.5^{c} ±0.31	48.9	65.8
α-cypermethrin	20.3^{b} ±0.18	12.2^{bc} ±0.12	59.3	70.3
Control	17.1^{a} ±0.06	9.6^{a} ±0.35	94.6	96.2
F. Value	21.51***	4.24**		
L.S.D.	0.915	1.102		

Numbers of the same letters have no significant difference.

Effectiveness of Teflubenzuron, Emamectin benzoate and α-Cypermethrin Treatments of The Fall Armyworm, *Spodoptera frugiperda* under Field Conditions:

There was considerable damage to maize plant were observed under all maize fields. The highest infestation of a maize plant by larvae of fall armyworm *Spodoptera frugiperda* was recorded before day one pre-application of insecticide.

The effectiveness of Teflubenzuron, Emamectin benzoate and α-Cypermethrin against *S. frugiperda* expressed after spraying at Kaha district, Qualubia Governorate and in Sanores district, Fayoum Governorate. The results obtained indicate that the highest percentage reduction of larval pupation in treatment by α-Cypermethrin after 10 days of treatment, whereas this value was 100%, and the lowest value by Teflubenzuron after 24h of treatment by 20.63% in Kaha district in Table (3). But the results obtained in the Sanores district in Table (4), found the highest percentage reduction of larval pupation in treatment by Emamectin benzoate after 10 days of treatment, whereas this value was 100%, and the lowest value by Teflubenzuron after 24h of treatment by 28.74%. The data indicates that the means of initial effect expressed as a percent of the reduction in *S. frugiperda* infestation after 24 hours and 3 days of a spray of Teflubenzuron, Emamectin benzoate and α-Cypermethrin treatment, were recorded 32.54, 72.62, and 75.49% respectively for Kaha district in Table (3), while the means of residual effect after 10 days of spray were recorded 85.51, 89.50, and 94.37% respectively. We found the residual toxicity of Teflubenzuron, Emamectin benzoate and α-Cypermethrin against *Spodoptera frugiperda* in Maize crops was 59.025, 81.06, and 81.255% respectively. Also, we estimated the data in the Sanores district in Table (4) of the means of the initial effect of reduction percent in *S. frugiperda* infestation after 24 hours and 3 days of a spray of Teflubenzuron, Emamectin benzoate and α-Cypermethrin treatment, were recorded 39.20, 79.77, and 70.66% respectively, while the means of residual effect after 10 days of treatment were recorded 85.99, 96.01, and 91.98% respectively. At end of experiments in the Sanores district in Table (4), we found the residual toxicity of Teflubenzuron, Emamectin benzoate and α-Cypermethrin against *Spodoptera frugiperda* in Maize crop was 62.595, 87.888, and 81.318% respectively. The present study confirmed that the treatment by Teflubenzuron, Emamectin benzoate and α-Cypermethrin reduces the larval population of *Spodoptera frugiperda*, which confirmed the result of Kumari *et al*., (2020) found that spraying of insecticide including Cypermethrin reduce the larval population of fall armyworm, *Spodoptera frugiperda* in maize. And agreed with Karina da Silva *et al.* (2020) who evaluate a significant reduce the larval population of *S. frugiperda* after spraying with the insecticides teflubenzuron and flubendiamide. Also agree with Mintesnot and Ebabuye (2019) who estimated that profenophos, cypermethrin and spinosad were giving maximum mortality of the sixth instar larva of fall armyworm, *Spodoptera frugiperda*. Also, Sileshi *et al*., (2022) found in the plot experiments sprayed with Alpha-Cypermethrin, Deltamethrin and Lambda-cyhalothrin significantly reduce the larval population of maize fall armyworm larvae after three days compared to the control. The present findings agreed with the results of Satyanarayana *et al.* (2010) who found that Emamectin benzoate 0.00725% was the most effective insecticide for reducing the larval population of *Spodoptera litura*.

Table3: Effectiveness of Teflubenzuron, Emamectin benzoate and α-Cypermethrin against *Spodoptera frugiperda* expressed as percentage reduction of larval pupation and residual toxicity after spraying on Maize crop at Kaha district, Qualubia Governorate, Egypt.

Treatments:	No. of larvae before spray:	No. of larvae and Reduction rate % in larval pupation as indicated days after spray application in Kaha district, Qualubia Governorate:												Residual Toxicity
		Initial effect:				Mean	Residual effect:						Mean	
		1 day		3 days			5 days		7 days		10 days			
		No	Red%	No	Red%		No	Red%	No	Red%	No	Red%		
Teflubenzuron	18	15	20.63	12	44.44	32.54 ^{a} ±0.61	6	74.36	4	85.18	1	97	85.51 ^{a} ±1.77	59.025
Emamectin benzoate	15	6	61.91	3	83.33	72.62^{c} ±1.18	3	84.61	2	91.11	2	92.79	89.50 ^{b} ±2.68	81.06
α-Cypermethrin	17	7	60.78	5	75.49	68.14 ^{b} ±0.67	2	90.95	2	92.16	0	100	94.37 ^{c} ±2.94	81.255
Control:	20	21	-	24	-	-	26	-	30	-	37	-	-	-
F. Value						77.035***							761.12***	
L.S.D.						2.437							3.23	

Numbers of the same letters have no significant difference.

Table 4: Effectiveness of Teflubenzuron, Emamectin benzoate and α-Cypermethrin against *Spodoptera frugiperda* expressed as percentage reduction of larval pupation and residual toxicity after spraying on Maize crop at Sanores district, Fayoum Governorate, Egypt.

Treatments:	No. of larvae before spray:	No. of larvae and Reduction rate % in larval pupation as indicated days after spray application in Sanores district, Fayoum Governorate:												Residual Toxicity
		Initial effect:				Mean	Residual effect:						Mean	
		1 day		3 days			5 days		7 days		10 days			
		No.	Red%	No.	Red%		No	Red%	No	Red%	No	Red%		
Teflubenzuron	13	11	28.74	9	49.65	39.20 ^{a} ±1.13	6	73.63	3	87.69	1	96.67	85.99 ^{a} ±2.87	62.595
Emamectin benzoate	14	5	69.92	2	89.61	79.77 ^{c} ±4.8	2	91.84	1	96.19	0	100	96.01 ^{b} ±4.52	87.888
α-Cypermethrin	15	7	60.70	4	80.61	70.66 ^{b} ±5.01	2	92.38	3	89.33	2	94.23	91.98 ^{b} ±7.0	81.318
Control:	16	19	-	22	-	-	28	-	30	-	37	-	-	-
F. Value						824.36***							145.56***	
L.S.D.						3.45							4.898	

Numbers of the same letters have no significant difference.

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