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Relation between different temperature and resistance to oraganic spinosad of *Spodoptera frugiperda* (Lepidoptera:Noctuidae)

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Abstract

Spinosade is one of the compounds recommended for use in biological control programs for fall armyworm *Spodoptera frugiperda* (Smith) (Lepidoptera:Noctuidae), due to its effectiveness, especially in young larval ages. In this study, we shed light on the extent of resistance of the fourth larval age to this compound and the extent of the effect of temperature on the effectiveness of the compound spinosade and on the degree of resistance to this compound. The information we found in this study indicates that the effects of the spinosad compound against the fourth larval instar of fall armyworm *S. frugiperda* differed according to different temperatures and concentrations, as the death rate reached its lowest rate, as it recorded 20.9 % in the resistant strain, at a concentration of 0.2ml/l. at a temperature of 25°C, but when increased temperature and concentration increase The death rate of the resistant strain reached 68.1% at a concentration of 3ml/l. and a temperature of 30°C. Showed that the rectifier coefficient that tested strain (RR) was (8.34 fold) when exposed to a temperature of 30°C, and the value of LC50 was (0.8343). Indicated that the rectifier coefficient that tested strain (RR) increased with decreasing temperature, as the RF was (13.1) at a temperature of 25°C, and value of LC50 was (1.345), the results show that the rate of decrease in the LC50 value reaches -2.5 in the sensitive strain, but in the resistant strain, it was different with different temperatures, as it ranged from -1.9, -1.6 and 1.4 at temperatures 30, 25 and 20°C. The higher the temperature with high concentration, the greater the toxicity of the spinosad compound, and vice versa. .

Introduction

Spodoptera frugiperda (Smith) (Lepidoptera:Noctuidae) is an economically important insect in Egypt. It attacks many agricultural crops, especially in Upper Egypt, including corn and sugar cane, causing severe damage in terms of the quantity and quality of crops, and because it is rapidly spreading and multiplying, its ability to infect and deteriorate crops have increased.

The level of infection by *Spodoptera frugiperda* larvae over 55 % caused 15-73 % in crops (Hruska and Gould, 1997). The use of chemical pesticides from different groups in the control of the larvae of this insect, especially the fourth larval age, led to the emergence of resistance. Organophosphates and Pyrethroids are the most used in Africa, due to resistance or this larvae to these insecticides (Abrahams *et al.*, 2017). The evolution of resistance in insect populations is quickly becoming a global agricultural problem and poses threats and causes danger to human health (Tabashnik, 2013).

Insect resistance to various pesticides is due to many reasons, including the ability of the insect to destroy the pesticide or the occurrence of structural changes in the insect's body that prevent the pesticide from reaching the site of impact.

Spinosad is a natural compound produced from the fermentation of soil bacteria *Saccaropolyspora spinosa*. Its toxicity to insects is due to its effect on the insect's nervous system. It is similar in the way it affects other chemical compounds such as (Thiamethoxam, imidacloprid, acetamiprid and dinotefuran). Spinosad has two modes of action, the first mode of action by effect of the nicotinic acetylcholine receptors located at the postsynaptic cell junctures, which results in excitation of the insect central nervous system ,paralysis and death, the second mode of action is affecting GABA-gated ion channels (Raymond, 2019).

As a result of exposure of the armyworm larvae to high and different doses for long periods of different pesticides, the characteristic of resistance appeared which requires a study to clarify the extent of the resistance of those larvae in terms of the effect of different concentrations on the larvae of the fourth age of the armyworm under different of temperatures.

Materials and methods

1. Insects:

Samples of maize crop infested with fall armyworm larvae were collected from Assiut Governorate in Egypt. The samples were transferred to the laboratory and the fourth instar larvae of armyworm were selected in preparation for different concentrations of spinosad compound. After transferring the larvae to the laboratory, they were placed in glass jars covered with a layer of transparent cloth under laboratory temperature conditions from 25 to 28℃. In this study, the sensitive strain that was bred under laboratory conditions and away from any chemical pesticides was used to measure the resistance coefficient.

2. Bioassay:

In this experiment, five different concentrations of spinosad compound, Tracer 24% SC (0.2-0.4 -0.8-1.5-3 ml/l.) were used on the field strain and the sensitive strain, under three different temperatures, which are 20° C, 25℃ and 30℃. Five different concentrations of Tracer 24%SC compound (Spinosad) were prepared. Each concentration contained three replicates, and each replicate contained 50 larvae of the fourth larval age. The larvae were placed on castor leaves that had been previously sprayed with the previous concentrations. The death rate was calculated after 24 hrs. of treatment at different temperatures.

3. Analysis:

The corrected death rate was calculated using Abbott's formula, (1925), calculating the LC50 and LC90 concentrations using the ldpline-Ehab program, according to Finney (1971). The factor resistance (RF) was calculated by LC50 of the resistant strain / LC50 of the susceptible strain (Wearing and Calhoun, 2005). Temperature coefficient (higher of LC50/ lower of LC50) according to Musser and Shelton (2005).

Results and discussion

In Table (1) the results show that the highest death rate was for the susceptible strain, which reached 91.1 % at a concentration of 3ml/l. of spinosad compound, at a temperature of 30℃. The table also shows that the lowest death rate was recorded for the resistant strain (RR), as it was 20.9% at a concentration of 0.2 ml/l. of spinosad compound at a temperature of 25℃. Table (1) also indicates that a rise in temperature to 30, increased the mortality rate, reaching 68.1 for resistant strain and 91.1 for sensitive strain at a concentration of 3 ml/l.

Table (1): Effect of different temperatures on response of *Spodoptera frugiperda* strains after treated with different concentrations of spinosad after 24 hrs.

Strains	Concentration (Ml/L.)	Mortality% after 24 hrs.		
		30°C	C 25°	C 20° 25
S.S.	0.2	56.1	58.9	58.9
	0.4	69.8	69.3	65.7
	0.8	78.0	76.0	78.0
	1.5	89.3	81.5	80.9
	3.0	91.1	88.0	88.9
R.S.	0.2	36.5	20.9	32.1
	0.4	41.2	34.4	39.9
	0.8	48.1	49.9	42.5
	1.5	50.3	51.0	50.0
	3.0	68.1	60.9	60.5

S.S: Sensitive stain, R.S: Resistant strain.

Table (2) shows that the rectifier coefficient that tested strain (RR) was (8.34 fold) when exposed to a temperature of 30°C and the value of LC50 was (0.8343) with Slope (0.6670±0.138) and χ2(df) were 3.4123(7.8).

Table (2): Different responses of *Spodoptera frugiperda* strains after treated with deferent concentrations of spinosad under a temperature of 30° C.

Strains	Concentrations (Ml/L.)	N	LC50 (95%CL)ml/l..	2 χ (df)	Slope±S.D	RF
S.S.	0.2	50		0.5366		
	0.4	50	0.1(0.0718-	(6)	1.1766±0.217	-
	0.8	50	0.2221)			
	1.5	50				
	3.0	50				
R.S.	0.2	50	0.8343(0.5539-1.2891)			
	0.4	50		3.4123	0.6670±0.138	**8.34**
	0.8	50		(7.8)		
	1.5	50				
	3.0	50				

S.S: Sensitive strain; R.S: Resistant strain; N: Total number of larvae of the fourth larval age; Cl: Confidence interval; RF: Resistant facror.

Table (3) indicated that the rectifier coefficient that tested strain (RR) increased with decreasing temperature, as the RF was (13.1) at a temperature of 25°C, and the value of LC50 was (1.345) with Slope (0.8297±0.141) and χ2 (df) were 3.4809 (7.8).

Table (3): Different responses of *Spodoptera frugiperda* strains after treated with deferent concentrations of spinosad under a temperature of 25° C.

Strains	Concentrations (Ml/L.)	N	LC50 (95%CL)ml/l..	χ2 (df)	Slope±S.D	RF
S.S.	**0.2**	**50**				
	0.4	**50**	**0.102(0.0309-**	**0.1892**	**0.8052±0.154**	**-**
	0.8	**50**	**0.1859)**	**(7.8)**		
	1.5	**50**				
	3.0	**50**				
R.S.	**0.2**	**50**				
	0.4	**50**	**1.345(0.9775-**	**3.4809**	**0.8297±0.141**	**13.1**
	0.8	**50**	**2.099)**	**(7.8)**		
	1.5	**50**				
	3.0	**50**				

S.S.: Sensitive stain; R.S: Resistant strain; N: Total number of larvae of the fourth larval age; Cl: Confidence interval; RF: Resistant facror.

Table (4) indicated that the rectifier coefficient that tested strain (RR) increased with decreasing temperature, as the RF was (14.3) at a temperature of 20̊C, and the value of LC50 was (1.29) with Slope (0.5866±0.114) and χ2 (df) were 0.6591 (7.8). The results show that the lower the temperature, the greater the resistance of the larvae to the spinosad compound.

Table (4): Different responses of *Spodoptera frugiperda* strains after treated with deferent concentrations of spinosad under a temperature of 20̊C.

Strains	Concentrations (Ml/L.)	N	LC50 (95%CL) ml/l..	χ2 (df)	Slope±S.D	RF
S.S.	0.2 0.4 0.8 1.5 3.0	50 50 50 50 50	0.09(0.0304-0.1803)	0.1670 (7.8)	0.8222±0.155	-
R.S.	0.2 0.4 0.8 1.5 3.0	50 50 50 50 50	1.29(0.8355-2.6114)	0.6591 (7.8)	0.5866±0.114	**14.3**

S.S.: Sensitive stain; R.S: Resistant strain; N: Total number of larvae of the fourth larval age; Cl: Confidence interval; RF: Resistant facror.

Table (5) the results show that the rate of decrease in the LC50 value reaches -2.5 in the sensitive strain, but in the resistant strain, it was different with different temperatures, as it ranged from -1.9, -1.6 and 1.4 at temperatures 30, 25 and 20˚C. The higher the temperature, the greater the toxicity of the spinosad compound, and vice versa.

Table (5): Rate of decrease in LC50 and temperature coefficient to *spodoptera frugiperda* strains after treated with spinosad.

Strain	T (C̊)	RD	TC	
			5˚	**10˚**
S.S.	30 25 20	-2.5 -2.5 -2.5	0.002	0.01
R.S.	30 25 20	-1.9 --1.6 -1.4	0.51	0.44

T: Temperature (C̊); RD: Rate of decrease in LC50 $[(\log(\text{final LC50} - \text{initial LC50})/N]$;Temperature coefficient (higher of LC50/ lower of LC50).

From the obtained results, the recommended concentration of spinosad compound did not have an effective effect on the fourth age larvae of the fall armyworm *S. frugiperda***.** Therefore, the concentration was doubled to calculate the extent of resistance of these larvae. The results also show that temperatures influence the degree of larval resistance to this compound, as it was observed that the resistance to spinosad compound increases whenever the larvae of the fourth age of fall armyworm are exposed to a higher temperature, as the higher the temperature, the greater the resistance to these larvae.

The results obtained in this study are consistent with Bird *et al*. (2022) who found that the response of 11 field strains of *S. frugiperda* was very low to spinotoram ,spinosad and indoxacarb. Laboratory and field larvae of *S. frugiperda* resistance were also recorded in South and Central America (Okuma *et al*., 2018). Lira (2019) provided information that the inherited resistance of *S. frugiperda* to spinosad compound was a result of genetic changes and defects in growth because of exposure to this compound.

The characteristic of resistance in larvae of *S. frugiperda* also appeared in Brazil because of the use of spinosyns in controlling these larvae on maize and Bt-maize plants for long periods, which increased the risk of increasing resistance in this insect (Burtet *et al.*, 2017). Therefore, the tracer analysis of the inherited resistance to the soinotram gives important and useful information when developing strategies for the effect of the spinosyns group when controlling fall armyworm.

Seham (2023) concluded that when the temperature increased from 15 to 30, the toxicity of the compound spinosad increased against the cotton leafworm Spodoptera littoralis (Boisduval) (Lepidoptera: Noctuidae) and that the resistance decreased, respectively, at temperatures 15, 20, and 25˚C, and these results are consistent with this study.

To conclude, the resistance of the armyworm, *S. frugiperda* to the spinosad compound is affected by the temperature, as increasing the temperatures increases the effectiveness of the spinosad against the armyworm, and thus the resistance decreases and vice versa.

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