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EFFICACY AND PERSISTENCE OF SPINETORAM AGAINST THREE STORED PRODUCT INSECT PESTS

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ABSTRACT

The efficacy and the residual toxicity of spinetoram insecticide were evaluated in the laboratory at 26 ± 2°C and 60 ± 5RH against the adults of three insect species of stored products i.e., the rice weevil *Sitophilus oryzae* (L.), the lesser grain borer *Rhizopertha dominica* (F.) and the red flour beetle *Tribolium castaneum* (Herbst.). The obtained results showed that, the toxicity of spinetoram to the adults of the three insect species was concentration and exposure period - dependent.

The susceptibility of the insects varied from insect species to another. *R. dominica* adults were the most sensitive species, a complete mortality was achieved at 10ppm of spinetoram after 7days, followed by *S. oryzae* adults, 100.00% mortality was obtained after 14days of exposure, but *T. castaneum* adults,10ppm of spinetoram was not sufficient to achieve complete kill for the adults of *T. castaneum* even after the longest exposure periods (14days).

Meanwhile, complete reduction in F1-progeny of *R. dominica* was observed at the three highest used concentrations(10, 5 and 2.5ppm) while, the reduction in F1-progeny of *S. oryzae* and *T. castaneum* were 96.5 and 73.1% at the highest concentration (10ppm), respectively.

The residual toxicity results of spinetoram showed that, the initial concentration of(10ppm) gave 95.3,100.0 and 71.0% kill for *S. oryzae*, *R. dominica* and *T. castaneum*, resp. mortality levels remained stable to 2 months for *T. castaneum* and 3 months for *S. oryzae* and *R. dominica* then reduced gradually with the increase of the storage period. The residual effect was high against *R. dominica* adults and extended to 6 months with lowest reduction rate in mortality (27.8%).

INTRODUCTION

Many of traditional insecticides, known as grain protectants such as organophosphorous compounds leaves residues on grains and other products that are of concern for human health, while their extensive use is dangerous for environment (White and Leesch,1995; Arthur,1996). In addition, resistance in key stored product insects limited effectiveness of most traditional insecticides(Guedes *et al.,*1996 and Nayaka *et al.,* 2005), found that, *R. dominica*(F.) adults were resistant to cloropyriphos- methyl and pirimiphos- methyl, also (El-Lakwah *et al*., 2004) reported that, the lesser grain borer *R. dominica* (F.) adults were resistant to both malathion, pirimiphos- methyl. Therefore, alternative insecticides or pest management strategies are urgently needed to replace traditional insecticides. In a laboratory evaluation, (Subramanyam *et al*., 2002) found Spinosad, the fermentation product of the bacterium *Saccharopolyspora spinosa* to be an effective grain protectant on hard red spring, soft red winter and hard red wheat against several stored grain insect species. Spinosad has a unique

mode of action on insect nervous system at the nicotinic acetylcholine receptor and GABA receptor cites (Salgado 1997, 1998). Recently, spinetoram is a mixture of chemically modified spinosyns (spinosyn J and spinosyn L) produced by bacterium *Saccharopolyspora spinos*a colonies, it has the same mode of action of spinosad and it is active through contact and ingestion (Dripps *et al*., 2011). It is abroad spectrum insecticide with low mammalian toxicity (Mertz and Yoa 1990).The effectiveness of two formulations of spinetoram, water dispersible granules (WG), and suspension concentrate (SC-NC), against three major stored-grain beetle species, *R. dominica*, *S. oryzae*, *T. confusum* was evaluated in the laboratory. Adults of the above species were exposed on wheat treated with spinetoram at 1ppm (1mg/kg of wheat) for 0, 2, 4, 6, 8, 16, 40, and 72h. After this interval, mortality was recorded (immediate mortality) and the surviving individuals were transferred in untreated wheat, where mortality was recorded again 7 d later (delayed mortality). Then, all adults were removed, and the number of progeny production in the untreated substrate was measured 65d later. From the species tested, *R. dominica* was by far the most susceptible, given that immediate and delayed mortality for the 72-h exposure interval reached 44 and 97%, respectively. At the same time, progeny production was low, in most of the exposure intervals tested. In contrast, for *S. oryzae*, delayed mortality was negligible, with the exception of 72 h at the SC-NC formulation. However, in most of the cases examined, progeny production for *S. oryzae* was high. Finally, adult mortality for *T. confusum* was extremely low, regardless of the exposure interval and the type of the formulation. Nevertheless, offspring emergence of this species was low (Vassilakos, *et al.*, 2012).

The aims of the present study to evaluate the efficacy and residual toxicity of spinetoram to *Sitophilus oryzae* (L.); *Rhizopertha dominica* (F.) and *Tribolium castaneum* (Herbst.) on infested wheat seeds in the store.

MATERIALS AND METHODS

Spinetoram: spinetoram (Radiant 12% SC) is a mixture of (3-O- ethyl 5,6- dihydro spinosyn J and 3- O-ethylspinosyn L), formulation was obtained from Shoura chemicals com. under license of Dow Agro Sciences UK.

Insects: The rice weevil *S. oryzae* (L.), the lesser grain borer *R. dominica* (F.), and the red flour beetle *T. castaneum* (Herbst.) were used in the experiment.

Grain treatment: Stock solutions of spinetoram were prepared by dispersing the required amount of the insecticide in distilled water. Five ml from each concentration were added to 50g media (sterilized and conditioned wheat kernels in case of the rice weevil and the lesser grain borer or wheat flour in case of the red flour beetle) in jars of about 125ml volume to achieve 10, 5, 2.5, 1.25, 0.625 and 0.313ppm concentrations, and left 24hrs to evaporate the solvent.

Bioassay: Batches of 30 adult insects (1week old) were introduced to the jars. Three replicates for each concentration were used; the jars were

covered with muslin cloth and fixed with rubber band. All replicates of experiment were kept at 26 ± 2°C and 60 ± 5% RH. Mortalities were recorded after 2, 3, 5, 7 and 14days from treatment. Mortalities were corrected using Abbot's formula (1925). The adult insects were removed from the jars after the preceding holding period.

Number of F1-progeny was inspected after 75 days from treatment and reduction percentages in F1-progeny were calculated according to the following equation: Reduction = N0 - N1/ N0 x 100

N0=No. of adults emerged in control.

N1= No. of adults emerged in treatment.

The lethal concentrations of spinetoram were estimated using EPA probit analysis program (version1.5).

The residual toxicity test: The residual toxicity of spinetoram insecticide at 10ppm was investigated against the adults of above insect species for 6 months, 30adult insects were introduced to 50g of the treated or untreated samples that were taken monthly from wheat lots stored at 26 ± 2°C and 60 ± 5RH and adults mortality was recorded after 7days of exposure for the insecticide.

RESULTS AND DISCUSIONS

Effect of spinetoram: Results concerning effects of spinetoram on mortalities and reduction in F1-progeny of *S. oryzae, R. dominica* and *T. castaneum* are illustrated in Tables (1). Data revealed that, adult mortalities were increased with the rise of concentration and exposure time.

In case of *S. oryzae,* spinetoram at 10ppm gave approximately complete mortality (95.6%) after 14 days from treatment, while only 25.6% mortality was achieved at the lowest concentration (0.313ppm).

Reduction rates of F1-progeny at all tested concentrations were higher than mortality percentages and ranged between 26.1 - 96.5% at various concentrations, approximately complete inhibition of F1-progeny of *S. oryzae* adults (96.5%) was achieved at the highest concentration.

Results of *R. dominica* indicated that, average adult mortality reached (100.0%) after 7 days exposure at 10ppm concentration and at all concentrations after 14days exposure with exception of 0.625 and 0.313ppm.

After 5 days, mortalities were 82.2, 74.4, 56.7, 45.5, 36.7 and 33.3% at 10, 5, 2.5, 1.25, 0.625 and 0.313ppm, respectively. Reduction rates of F1-progeny of *R. dominica* were high at all concentrations and ranged between 96.0-100.0% at various concentrations. A complete inhibition in F1-progeny was achieved at the three highest concentrations.

T. castaneum adults were relatively less susceptibility to spinetoram compared with the others species tested. Adult mortality reached 71.1% at the highest concentration 10ppm and only 45.6% at 5ppm after 14days of exposure.

Table (1): Effect of spinetoram on mortalities and reduction in F_1– progeny of three stored product insects.

Concent-ration (ppm)	% Adult mortalities after indicated periods (days) ± S.D.					No. of F1- progeny after 75 days	% Reduction in F1- progeny
	2	3	5	7	14		
S. oryzae							
10	14.4 ±4.2	22.2 ± 4.2	78.9 ±4.2	87.8 ±4.2	95.6 ±1.6	14.3±2.5	96.5
5	3.3 ±2.7	11.1±4.2	63.3±5.4	72.2±4.2	85.6 ±4.2	24.7±4.5	93.9
2.5	0.0 ±0.0	4.4±1.6	28.9 ±4.2	47.7±4.2	68.9 ±5.7	33.3±8.5	91.8
1.25	0.0 ±0.0	1.1±1.6	12.2 ±3.1	30.0 ±5.4	51.1 ±6.9	63.3±6.2	84.4
0.625	0.0 ±0.0	0.0±0.0	4.4±1.6	13.3 ±5.4	46.7 ±8.2	139.0±5.4	65.7
0.313	0.0 ±0.0	0.0±0.0	1.1±1.6	11.1 ±3.1	25.6 ±4.2	299.7±6.6	26.1
Control	0.0 ±0.0	0.0±0.0	0.0±0.0	0.0 ±0.0	0.0±0.0	405.3±12.3	-
R. dominica							
10	20.0 ±2.7	27.8 ±1.6	82.2 ±3.1	100.0 ±0.0	100.0 ±0.0	0.0±0.0	100.0
5	17.8 ±1.6	20.0 ±2.7	74.4 ±4.2	92.2 ±3.1	100.0 ±0.0	0.0±0.0	100.0
2.5	8.9 ±3.1	12.2 ±4.2	56.7 ±2.7	80.0 ±5.5	100.0 ±0.0	0.0±0.0	100.0
1.25	5.5 ±3.2	8.9 ±4.2	45.5 ±3.2	63.3 ±5.4	100.0 ±0.0	2.0±1.2	98.4
0.625	2.2 ±1.6	5.5 ±1.6	36.7 ±5.4	56.7 ±2.7	97.8 ±1.6	3.3±1.2	97.6
0.313	0.0 ±0.0	2.2 ±1.6	33.3 ±2.7	47.7 ±4.2	95.5 ±1.6	5.0±0.8	96.0
Control	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	125.0±4.1	-
T. castaneum							
10	2.2 ±1.6	12.2 ±1.6	25.5 ±3.2	38.9 ±4.2	71.1 ±4.2	25.0±4.1	73.1
5	1.1 ±1.5	2.2 ±1.6	10.0 ±2.7	21.1 ±4.2	45.6 ±4.2	43.3±2.4	53.4
2.5	0.0 ±0.0	1.1 ±1.5	1.1 ±1.5	4.4 ±1.6	27.8 ±4.2	65.0±4.1	30.1
1.25	0.0 ±0.0	0.0 ±0.0	1.1 ±1.5	3.3 ±2.7	8.9 ±4.2	77.3±2.1	16.9
0.625	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	1.1 ±1.5	2.2 ±1.5	81.7±2.4	12.2
0.313	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	1.1±1.5	91.7±2.4	1.4
Control	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	93.0 ±5.9	-

S.D.= Standard deviation.

Reduction rates of F1-progeny were higher than mortality percentages, and ranged between 1.4 -73.1% at various concentrations.

The lethal concentrations of spinetoram are shown in Table (2) the mean values of LC_{50}, LC_{90}, LC_{95} and LC_{99} after 7days exposure were

2.5, 11.8, 18.4 and 42.1; 0.4, 5.9, 12.3 and 48.9 and 13.9, 64.1, 98.8 and 222.1ppm for *S. oryzae*, *R. dominica* and *T. castaneum*, resp.

The obtained data revealed clearly that adults of *R. dominica* were highly susceptible to spinetoram followed by *S. oryzae* and *T. castaneum* adults which were the least susceptible to the insecticide.

In this respect, Vassilakos *et al*., (2012) studied the efficacy of spinetoram against six stored grain insects, *S. oryzae*, *R. dominica*, *Prostephanus truncates*, *T. confusum, S. granarius and Oryzaephilus surinamensis.* Data revealed that, spinetoram is effective as a grain protectant, but its efficacy varies according to the target species, concentration and exposure intervals. *P. truncates* and *R. dominica* were by far the most susceptible, given that was close to 100% after 7 days on wheat treated or maize with 0.1ppm of spinetoram and negligible number of F1-progeny. On the other hand, *T. confusum* was the least susceptible; mortality

reached 95% only at 10ppm after 14days of exposure. Similarly, *O. surinamensis* was of limited susceptibility to spinetoram; only 95% mortality was achieved after 14days of exposure on wheat treated with 5ppm. Nevertheless, offspring emergence of these species was extremely low. For *S. granarius* and *S. oryzae*, a complete mortality (100%) mortality was recorded after 14days of exposure at 0.5 and 1ppm, resp. At these concentrations or higher, progeny production was notably reduced.

Table (2): Lethal concentrations of spinetoram to the adults of the three insect species at 7days exposure period.

Insect Species	Lethal concentrations (ppm) and their 95% confidence limits				Slope ± S.E
	LC_{50}	LC_{90}	LC_{95}	LC_{99}	
S. oryzae	2.5 (2.0 - 3.0)	11.8 (8.8-18.4)	18.4 (12.8 - 32.4)	42.1 (25.2 -94.5)	1.9 ±0.24
R. dominica	0.4 (0.3 - 0.6)	5.9 (2.8 - 11.9)	12.3 (6.9 - 32.3)	48.9 (20.9 -211.9)	1.1 ±0.15
T. castaneum	13.9 (10.5-22.7)	64.1 (35.0-193.0)	98.8 (49.0-356.3)	222.1 (91.8 -1127.6)	1.9 ±0.03

S.E = Standard error of regression line.

Residual toxicity of spinetoram to the adults of the three tested insects:

Data of the residual toxicity of spinetoram to the adults of the three tested insects are given in Table (3).The results showed that, the initial concentration gave 95.3,100.0 and 71.0% kill for *S. oryzae*, *R. dominica* and *T. castaneum*, resp. these mortality levels remained stable to 2 months for *T. castaneum* and 3months for *S. oryzae* and *R. dominica* then reduced gradually with the increase of the storage period to reach about 47.8, 72.2 and 25.6% after 6months for aforementioned insect species, resp. residual effect of spinetoram at 10ppm was extended to 6 months for the adults of *R. dominica* with the lowest values of reduction rate in mortality (27.8%)when compared with other tested insect species(Fig.1).In the study conducted by (Vassilakos, *et al*., 2014),results showed that mortality levels of *S. oryzae*, *R. dominica* and *T. confusum* remained stable for the whole 8-month testing period and the residue analysis results showed that spinetoram was stable throughout the entire experimental period(8months), without a noticeable degradation with time.

Also, the obtained results during this study are in harmony with the findings of other investigators (Vassilakos and Athanassiou 2013; Athanassiou and Kavallieratos, 2014).

The achieved results indicated that spinetoram is effective against main stored product insect species infest wheat grains during storage, but its efficacy varies according to the insect species, concentration and exposure interval.

Further researches are required to study the combination effect of spinetoram with other insecticides for control OP-resistance insect species such as *R. dominica*.

Table(3):Residual toxicity of spinetoram at 10ppm to the three insect species

Time month	% adult mortality after 7 days from exposure ± S.D. and reduction rate in mortality at various intervals (months)						Control
	S. oryzae	R (%)	*R. dominica*	R (%)	*T. castaneum*	R (%)	
0	95.3±1.2	0.0	100.0±0.0	0.0	71.0±2.9	0.0	0.0
1	95.0±1.6	0.3	100.0±0.0	0.0	70.0±0.8	1.4	0.0
2	94.3±1.2	1.0	100.0±0.0	0.0	68.7±1.7	3.2	0.0
3	93.2±3.1	2.2	100.0±0.0	0.0	56.4±5.4	20.6	0.0
4	82.7±2.1	13.2	95.6±1.6	4.4	47.8±4.2	32.7	0.0
5	63.3±5.4	33.6	85.7±2.1	14.3	30.0±5.4	57.7	0.0
6	47.8±4.2	49.8	72.2±4.2	27.8	25.6±4.2	63.9	0.0

S.D.= Standard deviation R= Reduction rate in mortality.

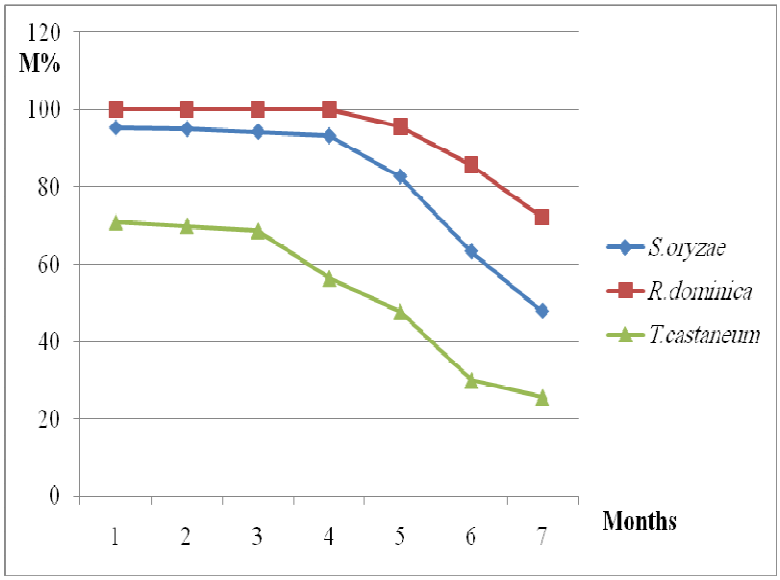

Fig.(1):Residual toxicity of spinetoram at 10ppm to the three insect species

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فعالية وبقاء مبيد spinetoram ضد ثلاثة من حشرات المواد المخزونة

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تم تقييم فعالية مبيد spinetoram وكذلك سمية الأثر المتبقي له معملياً على درجة حرارة 26 ± 2°م ورطوبة نسبية 65 ± 5% ضد ثلاثة أنواع من الحشرات التي تصيب المواد المخزونة وهى سوسة الأرز وثاقبة الحبوب الصغرى وخنفساء الدقيق الكستنائية وقد أوضحت النتائج أن سمية المبيد تتوقف على التركيز ومدة التعريض. وأزداد التأثير السام للمبيد بزيادة التركيز ومدة التعريض. واختلفت حساسية الحشرات من نوع لآخر حيث وجد أن الحشرات الكاملة لثاقبة الحبوب الصغرى أكثر الأنواع الحشرية حساسية للمبيد وذلك لموت كل الحشرات الكاملة بعد 7 أيام فقط من التعريض لتركيز 10 جزء في المليون ، يليها سوسة الأرز حيث تم الحصول على نسبة موت 100% بعد 14 يوم من التعريض على نفس التركيز وكانت خنفساء الدقيق الكستنائية أقل الأنواع المختبرة حساسية للمبيد، حيث وجد أن أعلى تركيز لم يكن كافيا للحصول على موت كامل لجميع الحشرات الكاملة لخنفساء الدقيق الكستنائية حتى مع أطول فترة تعريض (14 يوم).

كما أوضحت النتائج حدوث انخفاض تام في تعداد حشرات الجيل الأول لثاقبة الحبوب الصغرى على التركيزات الثلاثة العالية(10 ، 5، 2,5جزء في المليون)، بينما كان معدل الانخفاض في تعداد الجيل الأول لحشرتي سوسة الأرز وخنفساء الدقيق الكستنائية هو (73.1,96.5 %)على التوالي وذلك عند أعلى تركيز (10جزء في المليون).

وأظهرت نتائج الأثر الباقي للمبيد spinetoram أن أعلى تركيز عند بداية المعاملة قد أعطى نسب موت (95.3، 100.0، 71.0%) لحشرة سوسة الأرز، ثاقبة الحبوب الصغرى، وخنفساء الدقيق الكستنائية على التوالي، وظلت نسب ثابتة لمدة شهرين ضد خنفساء الدقيق الكستنائية وثلاثة شهور لحشرتي سوسة الأرز، ثاقبة الحبوب الصغرى ثم أخذت هذه النسب في الانخفاض تدريجيا بزيادة فترة التخزين ،وكانت سمية الأثر المتبقي من المبيد عالية على حشرة ثاقبة الحبوب الصغرى واستمر ذلك لمدة 6 شهور.