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Short Communication

Effect of Temperature on the Toxicity of Biorational Insecticides against *Sitophilus oryzae* (Linnaeus) in Stored Wheat

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AQ and HAAK designed the experiment, GM performed the experiment and analyzed the data. All the authors wrote the manuscript.

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ABSTRACT

The rice weevil, *Sitophilus oryzae* (Coleoptera: Curculionidae), is an important pest of stored grains including wheat, maize and rice. Although insecticides are used for the management of this pest, successful management could be compromised by prevailing environmental temperature since it has a significant effect on the toxicities of insecticides. The focus of the present study was to evaluate the effect of post-treatment temperature on the toxicity of four insecticides *viz*., spinosad, emamectin benzoate, lufenuron and thiamethoxam. For this purpose, toxicities of insecticides were tested at three different temperatures 20°C, 25°C and 30°C, on whole wheat grains which was artificially infested with *S. oryzae* under laboratory conditions. The toxicities of spinosad, emamectin benzoate, lufenuron and thiamethoxam increased 2.65, 1.59, 1.64 and 3.00 folds (positive temperature coefficient), respectively, with increasing temperature. The positive temperature coefficients of all the tested insecticides suggest that these insecticides may provide effective control of rice weevils under high temperature conditions.

Temperature plays an important part in the efficiency of an insecticide when applied in storage conditions. Evaluation of the temperature effect on the toxicity of insecticides against a target insect pest is an important part in the implementation of chemical based management strategies (Boina *et al*., 2009). It is a dynamic part of an environment that acts as a controlling as well as toxic factor (Mansoor *et al*., 2015). The change in the toxicities of an insecticides against different insects at different temperatures may be due to the differences in insects fertility, life cycle (Dreyer and Baumagartner, 1996; Infante, 2000), sex ratio (Zheng *et al*., 2008), and exposure of insects (Wilkinson *et al*., 1999). At high temperature, activity of insects becomes high (Cagan, 1998) and insecticide residual life decreases (Bobe *et al*., 1998; Arthur *et al*., 1992). The effect of temperature and relative humidity on insecticides is complex because it changes with the exposure interval and dose rate. Hence, increase in body metabolic activities at high temperatures may have resulted in increased susceptibility to insecticide. Relationship between temperature and toxicity may be calculated by temperature coefficient (Khan and Akram, 2014). Positive temperature coefficient means an insecticide is more toxic at high temperatures while insecticides with negative temperature coefficient are more toxic at low temperatures (Glunt *et al*., 2013). Several studies have shown the variances between the tested insect species, temperature ranges and in the toxicity within the class of insecticides (Muturi *et al*., 2011). Insecticides related to same class may have similar response to temperature. Some studies showed that organophosphate and carbamates have generally constant toxicities at all temperatures but some researchers have found minor negative and positive coefficient. At high temperatures insecticides related to pyrethroid class mostly have negative coefficient, but some studies revealed that against some species pyrethroids have positive temperature coefficient (Scott, 1995; Musser and Shelton, 2005).

In addition, biorational pesticides represent an alternative class of insecticides available for control of different insect pests (Ilyas *et al*., 2017), including stored grain insects. However, there is a lack of information on the effect of temperature on these insecticides. Studies on the efficacy of spinosad at different temperature ranges showed that the toxicity was not affected by the change in temperature (Fang and Subramanyam, 2003). But

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according to Athanassiou *et al*. (2008), efficacy of spinosad against *S. oryzae* was highly affected by temperature and with increase in temperature weevil mortality also increases even at low dose rates.

The aim of this research was to evaluate the temperature significance on the effectiveness of selected biorational insecticides against the rice weevil in wheat grains.

Materials and methods

Healthy adult cultures of *S. oryzae* were collected from grain markets of Faisalabad (Longitude: 73° 5' 0" E; Latitude: 31° 25' 0" N; Altitude: 192 m) in Punjab Province, Pakistan. Collected insects were reared on whole wheat grains at 26±1°C temperature and 70±5% relative humidity. Mixed sex and 2-3 weeks old *S. oryzae* adults were used in the experiments (Athanassiou *et al*., 2011). The study was approved by the University of the Punjab, Lahore, with the approval number No. D 1330/Acad.

Insecticide formulations used in the current study were: 240 SC spinosad [a microbial insecticide extracted from *Saccharopolyspora spinosa*], 1.9 EC emamectin benzoate [avermectin], 25 WG thiamethoxam [neonicotinoid], and 5.2 EC lufenuron [benzoylurea]. The grain commodity used in the bioassays was clean, untreated and uncontaminated wheat. These grains were purchased from grain markets of Lahore (Latitude: 31.5497◦ N; Longitude: 74.3436◦ E; Altitude: 216m).

Bioassays with all insecticides were done as described by Athanassiou *et al*. (2011) and Khan *et al*. (2016a) with few changes. Spinosad and emamectin benzoate were applied on wheat at five rates; 0.50, 0.75, 1.00, 1.50 and 2.00 ppm, whereas lufenuron and thiamethoxam were applied at 2.0, 4.0, 6.0, 8.0, 10.0 ppm, as a solution made in distilled water. For each insecticide at single dose rate, lots of 900g grains were required. To attain the required doses, the appropriate quantity of each insecticide was dissolved in distilled water and 90 ml solution of each insecticide was prepared. Then, on a tray a thin layer of grains for each insecticide were spread and treated with 9 ml of each insecticide dose separately and for uniform insecticide distribution grains were manually shaken for 5 min (Krishnamurthy *et al*., 2008; Athanassiou *et al*., 2011). Grains were allowed to dry before place in jars. From treated grain lot of individual insecticide, 100 g of grains were taken and placed in a plastic jar. In each jar, 30 adults of *S. oryaze* were added and the jars enclosed with a muslin cloth to prevent the insects escaping and also to facilitate aeration. The treated jars were maintained at 20°C, 25°C and 30°C. One jar containing grains treated with distilled water was served as control. All the bioassays were replicated thrice and mortality was counted after 21 days.

To find out the insecticide lethal concentration (LC_{50}), data of mortality against each concentration of an insecticide with three replicates were collected and analyzed for probit analysis in SPSS software (16.0 version). At LC_{50}, the toxicities of each insecticide were considered as different if the 95% confidence interval (CIs) did not overlap (Khan and Akram, 2014). For each tested insecticide, the ratio of higher LC_{50} to the lower LC_{50} was calculated as temperature coefficient. The temperature coefficient was considered as positive when the LC_{50} value lower at high temperature and negative when LC_{50} value is higher at low temperature (Musser and Shelton, 2005; Khan and Akram, 2014).

Results

The toxicities of all four tested insecticides were found to be positively linked to the tested range of temperature (Table I). The results of spinosad according to LC_{50} values

Table I.- Effect of temperature on toxicity of biorational insecticide against *Sitophilus oryzae*.

Insecticide	Temp (°C)	n [1]	LC50 [2](95% CI) µg/ml	Fit of probit line			Temp coefficient[3]	
				Slope	x^2(df)	P	5 °C	10 °C
Spinosad	20 °C	450	0.39 (0.29-0.47)	1.69 ± 0.20	(1.51) 3	0.679		
	25 °C	450	0.29 (0.21-0.35)	2.01 ± 0.22	(2.96) 3	0.398	1.34	
	30 °C	450	0.14 (0.82-0.27)	1.81 ±0.26	(3.70) 3	0.295	1.97	2.65
Emamectin benzoate	20 °C	450	0.36 (0.25-0.45)	1.46 ± 0.19	(1.39) 3	0.706		
	25 °C	450	0.27 (0.18-0.34)	1.60 ± 0.20	(0.05) 3	0.997	1.33	
	30 °C	450	0.22 (0.16-0.28)	2.34 ± 0.27	(2.24) 3	0.523	1.18	1.59
Lufenuron	20 °C	450	5.21 (4.58-5.90)	2.29 ± 0.26	(4.50) 3	0.212		
	25 °C	450	4.30 (2.38-6.18)	2.20 ± 0.26	(8.16) 3	0.043	1.21	
	30 °C	450	3.15 (0.00-5.56)	2.30 ± 0.26	(20.79)3	0.000	1.36	1.64
Thiamethoxam	20 °C	450	3.73 (0.00-6.98)	1.57 ± 0.25	(10.89)3	0.012		
	25 °C	450	2.21 (1.47-2.81)	1.65 ± 0.26	(5.23)3	0.156	1.69	
	30 °C	450	1.24 (0.00-2.58)	1.73 ± 0.29	(9.06)3	0.028	1.77	3.00

[1]Total number of *S. oryzae* tested. [2]Median lethal concentration. [3]Temperature ratio of higher to lower LC_{50} value.

showed 1.34 and 1.97 folds increase in toxicity at temperature 25°C and 30°C when compared with toxicity at 20°C (non-overlapping of 95% CIs). The results also indicated the positive temperature coefficient with 2.65 fold for the tested temperature ranges. Similarly, as compared to the values at 20°C, the toxicity of emamectin benzoate based on LC_{50} values was increased 1.33 and 1.18 folds at temperature 25°C and 30°C, respectively. The temperature coefficient of tested ranges for emamectin benzoate was also positive with 1.59 fold increase. The toxicity of lufenuron also showed positive connection at all temperatures. The results when compared with 20°C (non-overlapping of 95% CIs) showed 1.21 and 1.36 fold increased in toxicity at high temperature. Findings of thiamethoxam showed a positive temperature connection with increase in toxicity from 1.69 to 1.77 folds at 25°C and 30°C when compared with toxicity at 20°C. The overall temperature coefficients for lufenuron and thiamethoxam were 1.64 and 3.00, respectively, for the tested range of temperatures.

In general, all tested insecticides showed positive temperature coefficients but the efficacy of thiamethoxam was maximum as thiamethoxam (3.00) > spinosad (2.65) > lufenuron (1.64) > emamectin benzoate (1.59).

Discussion

In insects' body, different metabolic activities which are responsible for the normal working of the nervous system and degradation of an insecticide are extremely dependent on temperature (Montgomery and Macdonald, 1990). Our results showed that the toxicity of spinosad was temperature dependent as it increased at 25°C and 30°C. These results are in accordance with Athanassiou *et al*. (2008) findings who reported increased mortality after spinosad treatment when the temperature was increased from 20°C to 30°C. One reason of mortality at high temperature may be that *S. oryzae* adults are more responsive at high temperatures compared to other insects. Spinosad act as a contact insecticide and at high temperature (30°C) which is close to the temperature required for their development (Khan *et al*., 2014) contact of adult weevils with insecticide increases, hence results in high mortality. Emamectin benzoate act as an activator of chloride channel by binding GABA receptors and disturb the nerve signals in arthropods (Grant, 2002; Khan *et al*., 2016b). Due to the binding of GABA receptors permeability of chloride ions increases within the cells (Rodriguez *et al*., 2007) as a result the transmission in nerves is reduced. The mortality of insects due to the insecticides depends upon different factors like temperature, dose rate and exposure time (Khan and Akram, 2017; Yasoob *et al*., 2017). The current study on the toxicity of emamectin benzoate showed a positive temperature connection with 1.33 and 1.18 fold increases at 20°C to 30°C temperature. Previously, Kavallieratos *et al*. (2009) evaluated the abamectin effectiveness against *T. confusum, R. dominica* and *S. oryzae* on wheat and maize at two temperatures (25°C and 30°C), and reported that efficiency increases with the increase in dose rate, temperature and insects' exposure time.

Lufenuron (CSI) has been used to manage the larvae of various insect's species like Lepidoptera (Saenz-de-cabezon *et al*., 2006) Coleoptera (Ahire *et al*., 2008), Diptera (Khan *et al*., 2016c) and Homoptera (Gogi *et al*., 2006). It is used on different crops including maize, cotton, and ornamentals. Lufenuron affects the moulting process and develops abnormalities by affecting the physiological processes (Sammour *et al*., 2008). We have shown 1.21 and 1.36 folds increase in toxicity of lufenuron at 25°C and 30°C temperature when compared with LC_{50} values at 20°C. Recent work on lufenuron done by Ali *et al*. (2016) showed that it is an effective chitin synthesis inhibitor against *T. castaneum*. The results of thiamethoxam showed that toxicity varies 1.69 and 1.77 folds at high temperatures when compared to the values at low temperature. These results are in accordance with the Arthur *et al*. (2004) findings in which wheat containing *S. oryzae,* and *R. dominica* was exposed with different doses at three temperatures and they concluded that mortality increased with increase in temperature, insecticide dose and insect exposure time. All the tested insecticides can better perform in a hot environment as compared to cold conditions. As in Punjab average temperature in June has been reported to be approximately 38°C (Anonymous, 2013). Hence, qualitative and quantitative losses due to *S. oryzae* in stored grain commodities can be controlled with appropriate management. This control could be achieved only with the selection of proper insecticide which is effective in the storage season. The present study highlighted that for highly efficient control of *S. oryzae* in wheat grain in warm environment, it is highly recommended to use biorational insecticides at high temperatures.

Conclusion

The efficacy of all insecticides was temperature dependent as it increased with increase in temperature. All tested insecticides revealed the positive temperature coefficient and may serve as a potential applicant to control *S. oryzae* in stored wheat under warm climatic conditions. However, further studies should be conducted at temperature ranges other than the studied ones in present study for the purpose to determine the highest temperature range (above 30°C) at which toxicity stop to increase.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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