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TOXICITY OF FENVALERATE ON LARVAE OF THE SUSCEPTIBLE AND RESISTANT STRAINS OF *TRIBOLIUM CASTANEUM* (HERBST)

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Abstract: Five-day old larvae of the susceptible (FSS-II) and organophosphorus-resistant (PH-I) strains of the red flour beetle *Tribolium castaneum* were exposed under laboratory conditions to food treated with 100, 250, 500 and 1000 ppm of a synthetic pyrethroid Fenvalerate up to adult emergence. The larval mortality was assessed at 1-, 3-, 7- and 15-days post-exposure, and up to pupation. PH-I was found less susceptible to Fenvalerate than FSS-II which required 1.2 to 3.1 fold more insecticide to induce 50% mortality. The pyrethroid treatments significantly increased the larval and pupal periods (P<0·05) in both the strains and the formation of pupal and adult progenies was adversely affected (P<0·001).

Key words: Fenvalerate, *Tribolium castaneum*, mortality, developmental periods, progeny recovery.

mvivsk: M‡elYvMv‡i AvUvi jvj weUj *Tribolium castaneum*-Gi KxUbvkK ms‡e`bkxj (FSS-II) I AMv‡bvdmdivm-mnbkxj (PH-I) †÷Bb `wUi 5 w`b eq‡mi jvfv‡K 100, 250, 500 I 1000 wcwcGg gvÎvi GKwU cvBwi_‡qW KxUbvkK, †dbfv‡j‡iU wgwkZ Lv‡`¨i g‡a¨ Aegw³i 1-, 3-, 7- I 15-w`b ci Ges wcDcv `kvq DcbxZ nIqvi mgq chš jvfv `kvi gZ¨nvi wbYq Kiv nq| 50% ‡cvKvi gZ¨i Rb¨ PH-I †÷BbwU‡Z FSS-II †÷Bb A‡c¶v 1.2-3.1 ¸Y †ekx KxUbvkK c‡qvRb c‡o| ZvQvov KxUbvk‡Ki cfv‡e jvfv I wcDcv `kvi ewׇi ¯vqxZ ZvrchcYfv‡e (P<0.05) `xNwqZ nq Ges wcDcv I cvßeq® †cvKvi Awefvel ZvrchcYfv‡e (P<0.001) K‡g hvq|

Introduction

Grains in storage are damaged by the activities of several species of insect pests, the commonest being the beetles and moths, leading to loss in qualities such as weight, quality, texture, taste, colour, nutritional and commercial values and seed viability. Majority of these storage insect pests are coleopterans and the most damaging species belong to the genera *Sitophilus* and *Tribolium* (Marsans 1987; Pinto *et al.* 1997). The red flour beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) is an ubiquitous pest of economic importance which damages the products at both larval and adult stages. Due to severe infestations the flour may have a characteristic pungent odour and pinkish-brown in colour by the secretion of quinones (Markarian *et al.* 1978), affecting the viscous and elastic properties of the flour and creating a taint which may cause gastric disturbances if used as food (Payne 1925; Engelhardt *et al.* 1965; Mondal 1992). To avoid these, *T. castaneum* has usually been controlled primarily by the use of chemical insecticides (O'Donnell 1980; Evans 1985; Binns 1986). The development of resistance among populations of this species against organochlorides, organophosphates and certain fumigants has been reported throughout the world (Dyte and Blackman 1970; Zettler and Jones 1977; Zettler 1982; Saleem and Shakoori 1990, Zettler and Cuperus 1990). The resistance and contamination problems have, therefore, brought about interest in the use of a safer insecticide, like the synthetic pyrethriods due to their significant insecticidal properties (Elliott and Janes 1973; Elliott *et al.* 1978). The use of pyrethroids became worldwide because of their good knock down and lethal activity to insects, low mammalian toxicity, photostability, high degradability and effective at minimum dose (Barlow *et al.* 1971; Hadaway 1972). Because of insecticidal and lethal activity, many researchers have done a plenty of works on synthetic pyrethroids for determination of lethal dose and enzymatic activities against a number of insects (Tabassum *et al.* 1998; Mujeeb and Shakoori 2007; Yousuf *et al.* 2008). The purpose of this study was to evaluate the toxic effects of a synthetic pyrethroid, fenvalerate against a susceptible (FSS-II) and an organophosphorus-resistant (PH-I) strains of *T. castaneum* for successful control of this noxcious stored products species.

Materials and Methods

Mass rearing of the beetles: FSS-II and PH-I strains of the beetles were cultured on a whole meal wheat flour and yeast medium at the Insect Research Laboratory, Department of Zoology, Rajshahi University. The culture was maintained in glass jars (25cm × 11cm) at 30±1ºC in an incubator without any light and humidity control. The flour was sterilized at 60ºC for 3h. About half of each jar was filled with flour-yeast medium in which 300 unsexed beetles of each strain were introduced separately. The mouths of the jars were

covered with coarse cloth, tied with rubber bands, to avoid escape of the beetles. The medium was sieved on the following day to collect eggs that were kept in Petri dishes for hatching. Newly-hatched larvae were cultured on the same food medium to obtain 5-day old larvae for the experiment.

Insecticide used: Technical grade of the synthetic pyrethroid, fenvalerate (98%) used in the present investigation was supplied by the Department of Agricultural and Environmental Sciences, University of Newcastle upon Tyne, UK, as a liquid. This widely used pyrethroid is a clear yellow, viscous liquid having broad-spectrum against insects and chemically it is cyano (3-phenoxyphenyl) methyl-4-chloro-α-(1-methyl-ethyl) benzeneacetate.

Bioassays: For determination of larval dose-mortality, developmental periods, and progeny (pupal and adult) recoveries, four different concentrations of the chemical *viz.* 100, 250, 500 and 1000ppm were prepared by mixing the insecticide with requisite amounts of flour. Acetone was used as the solvent which was allowed to evaporate for 3h prior to introduction of larvae in the food medium. Twenty five 5-day old larvae of FSS-II and PH-I strains of *T. castaneum* were introduced separately into each Petri dish (9-cm diameter) provided with fenvalerate treated food up to adult emergence. The same number of insects was exposed to only acetone treated food maintained as controls. Three replicates were used for each treatment and control. Petri dishes were kept in an incubator at 30 ± 1ºC without any light and humidity control. Dead larvae were counted at 1-, 3-, 7- and 15-day post exposure, and up to pupation. The percentage mortalities were corrected by the Abbott's (1925) formula as follows:

$$\text{Corrected (\%) mortality} = \frac{\text{Test mortality (\%)} - \text{Control mortality (\%)}}{100 - \text{Control mortality (\%)}} \times 100$$

The corrected mortalities were then subjected to Probit analysis following the methods by Busvine (1971), the regression lines were drawn and the LC_{50} values were determined. Larvae were regularly checked for pupation while noting the larval periods. After pupation, insects were collected and kept in Petri dishes for adult eclosion. The number of adults that emerged from different concentrations was recorded for computing the pupal period. The numbers of pupal and adult progenies were also noted.

The percentages of reduction in pupal and adult progenies were calculated using the formula, PR (percent reduction) = $(C_r - T_r) / C_r \times 100$, where C_r is the mean (%) recovery in controls and T_r is the mean (%) recovery in treatment groups. Data on all the parameters finally were subjected to analysis of variance and the differences between the means were determined by the Tukey's multiple comparison procedure.

Results and Discussion

Fenvalerate was effective against both the strains of *T. castaneum*. The results are summerised in the following paragraphs.

Concentration-mortality response: LC_{50} values for 5-day old larvae of *T. castaneum* exposed to various concentrations of fenvalerate at different exposure periods are shown in Table 1. PH-I strain showed more tolerance, requiring 1.2-3.0 fold more chemical to kill 50% larvae than that in FSS-II. Regression lines indicated positive relationships between the concentrations and mortalities, i.e. the mortalities increased with increasing concentrations (Figs. 1 and 2). The present findings therefore showed that fenvalerate was toxic to both strains of *T. castaneum*, although a complete control would require higher concentrations than those used in the present study.

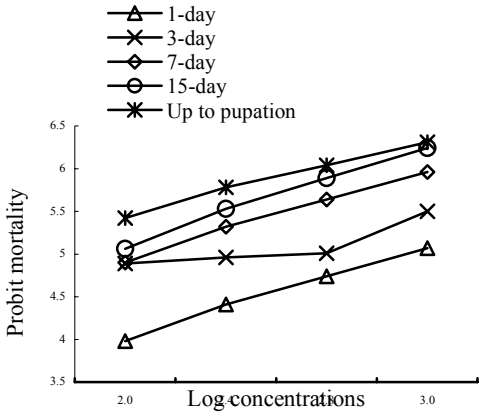

Fig. 1. Probit mortality regression line for *T. castaneum* larvae of FSS-II strain when exposed to fenvalerate-treated food for different durations.

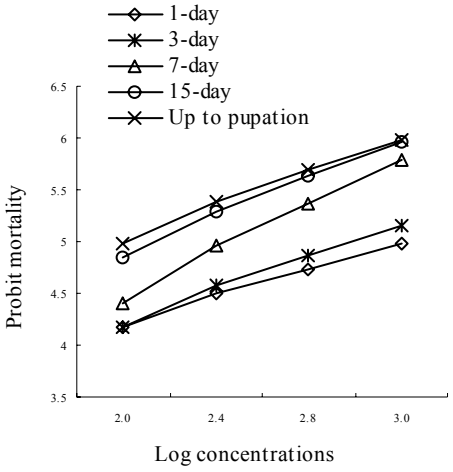

Fig. 2. Probit mortality regression line for *T. castaneum* larvae of PH-I strain when exposed to fenvalerate-treated food for different durations.

Effects of fenvalerate on progeny production: The pyrethroid caused significant reduction in pupal ($F_{4/4}$= 135.81, P< 0.001) and adult ($F_{4/4}$ = 173.17, P< 0.001) progenies in FSS-II and PH-I strains of *T. castaneum* (Table 2). The larvae that survived and succeeded pupation leading to adult emergence decreased with increasing concentrations. The adult progeny production in FSS-II strain was completely suppressed at 1000ppm while it was 97% in PH-I strain as compared to the controls.

Effects of fenvalerate on developmental periods: The larval and pupal periods were gradually increased from lower to higher concentrations of the insecticide (Table 3). Analysis of variance showed that fenvalerate significantly lengthened the larval ($F_{3/3}$ = 26.28, P<0.05) and pupal ($F_{3/3}$ = 19.99, P<0.05) periods in *T. castaneum* strains.

Table 1. Lethal concentrations of fenvalerate against 5-day old larvae of *T. castaneum* at different exposure periods.

Exposure periods (days)	Strains	LD_{50} (ppm)	Regression equation	χ^2-values (df)
1	FSS-II	872.06	1.79 + 1.09x	0.62 (2)
	PH-I	1057.63	2.56 + 0.81x	0.56 (2)
3	FSS-II	462.56	2.30 + 1.07x	2.50 (2)
	PH-I	682.66	2.21 + 0.98x	1.40 (2)
7	FSS-II	124.26	2.78 + 1.06x	0.76 (2)
	PH-I	238.63	1.65 + 1.38x	0.18 (2)
15	FSS-II	88.55	2.70 + 1.18x	2.89 (2)
	PH-I	140.46	2.55 + 1.14x	1.97 (2)
Up to pupation	FSS-II	33.47	3.65 + 0.98x	0.98 (2)
	PH-I	105.19	2.95 + 1.02x	1.27 (2)

Table 2. Effect of Fenvalerate on the production of pupal and adult progenies from *T. castaneum* larvae.

Strains	Concentrations (ppm)	Pupal recovery (%)	* PR	F-values	Pupal recovery (%)	* PR	F-values
FSS-II	0 (Control)	85.00^{a}	—	$^{(a)}135.81^{***}$	73.33^{a}	—	$^{a)}173.17^{***}$
	100	25.00^{c}	70.59		16.67^{c}	77.27	
	250	10.00^{e}	88.24		6.67^{d}	90.90	
	500	6.67^{f}	92.15		3.33^{e}	95.46	
	1000	1.67^{g}	98.04		00	100	
PH-I	0 (Control)	83.33^{a}	—	$^{(b)}3.91^{ns}$	73.33^{a}	—	$^{(b)}4.64^{ns}$
	100	35.00^{b}	58.00		25.00^{b}	65.91	
	250	21.67^{d}	74.00		16.67^{c}	77.27	
	500	10.00^{e}	88.00		5.00^{d}	93.18	
	1000	3.33^{g}	96.00		1.67^{f}	97.72	

Note: (a) = between concentrations, (b) = between strains; *** P < 0.001, ns = not significant; *PR = percent reduction over control. Means followed by dissimilar letters within each column are significantly different by Tukey's multiple comparison tests (P<0.05).

Table 3. Developmental periods (days) of fenvalerate treated *T. castaneum* larvae.

Strains	Concentrations (ppm)	Larval period (days)	F-values	Pupal period (days)	F-values
FSS-II	0 (Control)	22.47 ± 1.45^{a}	$^{(a)}26.28^{*}$	5.45 ± 0.50^{a}	$^{(a)}19.99^{*}$
	100	32.60 ± 1.18^{bc}		9.50 ± 1.28^{bc}	
	250	34.17 ± 1.17^{b}		9.25 ± 1.09^{bc}	
	500	37.75 ± 1.71^{d}		10.00 ± 1.00^{cd}	
	1000	NA		NA	
PH-I	0 (Control)	22.64 ± 2.76^{a}	$^{(b)}6.87^{ns}$	5.61 ± 0.49^{a}	$^{(b)}0.02^{ns}$
	100	29.86 ± 1.39^{c}		8.07 ± 0.77^{b}	
	250	29.47 ± 1.45^{c}		9.60 ± 0.66^{cd}	
	500	33.67 ± 1.87^{b}		10.67 ± 0.47^{d}	
	1000	NA		NA	

Note: (a) = between concentrations, (b) = between strains; * $P < 0.05$, ns = not significant. Means followed by dissimilar letters within each column are significantly different by Tukey's multiple comparison tests ($P<0.05$); NA = not applicable.

Fenvalerate used in the present study induced higher mortalities in both FSS-II and PH-I strains of *T. castaneum*. Yadav (1987) reported that the synthetic pyrethroids, deltamethrin and cypermethrin were most toxic to 13 stored product insects including *T. castaneum.* Bry *et al.* (1980) recorded 100% mortality for 1st instar larvae of *Attagenus megatoma* using permethrin. Similar effects of deltamethrin, cypermethrin, permethrin and fenvalerate have been reported for *Callosobruchus maculatus* and *C. chinensis* (Rahman and Yadav, 1987). However, O'Brien (1967) commented that pyrethroids may affect the sodium and potassium permeability and nitrogen metabolism in insect cells. In addition, pyrethroids may also affect the peripheral and central nervous systems causing rapid paralysis and eventual death (O'Brien, 1967).

Faruki and Khan (2004a, b) observed significantly higher reductions in pupation and adult emergence when larvae of *Cadra cautella* were reared on cypermethrin-treated groundnuts. Reductions in emergence of *C. maculatus* and *C. chinensis* were recorded from treatments of various developmental stages with different pyrethroids (Rahman and Yadav 1987). Significantly reduced pupation and adult emergence in the Indian mealmoth, *Plodia interpunctella* were also noted by Arthur (1997, 1999) when 5th instar larvae were exposed to deltamethrin and cyfluthrin residues for short periods. Shour and Crowder (1980) recorded that in larvae of *Chrysoperla carnea,* topically treated with permethrin or fenvalerate, the rate of pupation was significantly reduced. Tabassum *et al.* (1998) and Yousuf *et al.* (2008) working with *Alphitobius diaperimus, Sitophilus oryzae* and *T. castaneum* reported that pyrethroids were very much effective in reducing their population either by killing or inhibiting progeny that agreed with the present findings. Significantly lengthened developmental periods observed in the present treated insects that corroborate to the findings of Faruki and Khan (2004a, b).

Conclusion

The present results showed that fenvalerate effectively increased the mortality, lengthened the developmental periods, and reduced the production of pupal and adult progenies in both susceptible and resistant strains of *T. castaneum* which is very much desirable in stored products pest management programmes. It may therefore be concluded that fenvalerate may be used to protect stored product commodities from insect infestations.

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