Efficacy of Mixtures of an Organophosphate Malathion and a Synthetic Pyrethroid Deltamethrin against Lesser Grain Borer, Rhyzopertha dominica*

NIGHAT S. ALI, M. MUNIR, S. SHAHID ALI AND A. R. SHAKOORI
Toxicology and Biochemistry Laboratory, Department of Zoology (NSA, SSA) School of Biological Sciences (ARS), University of the Punjab, Quaid-i- Azam Campus, Lahore- 54590, Pakistan

Abstract.- Adults of six strains of stored grain pest, Rhyzopertha dominica viz. Chichawatni (C), Karachi (K), Wazirabad (W), Sialkot (S), Lahore (L), and Multan (M) were treated with an organophosphate malathion, and a synthetic pyrethroid, deltamethrin (Decis), alone and in two different combinations. C strain was found to be most resistant to malathion (LC50, 115.50 ppm), whereas M strain was least resistant (LC50 12.40 ppm). On the other hand, M strain was most resistant to deltamethrin (LC50 10.55 ppm), whereas L strain was most susceptible (LC50 2.83 ppm). A mixture of malathion : deltamethrin (10:1) was most effective against K, S and M strain with LC50 of 4.71, 5.33 and 8.38 ppm, respectively, whereas mixture 10:1.5 and 9:2 was most effective against W strain (LC50 4.52 and 3.13 ppm) and M strain (LC50 8.25 and 5.27 ppm), respectively. R. dominica did not show any definite pattern of susceptibility to both types of mixtures. It is concluded that mixture 10:1 with LC50 ranging between 4.53 to 24.94 ppm, mixture 10:1.5 with LC50 ranging between 4.52 to 8.74 ppm and mixture 9:2 with LC50 ranging between 3.13 to 61.53 ppm were found to be most effective for almost all the strains.

Key words: Deltamethrin (Decis), malathion, pyrethroid, organophosphate, stored grain pests, Rhyzopertha dominica, pest control, LC50.

INTRODUCTION

Rhyzopertha dominica, the Lesser Grain Borer is a pest of economic significance in the United States of America, Southern Canada, Argentina, New South Wales, South East Australia and Indo-Pakistan sub-continent (Cuperus et al., 1986 Shakoori et al., 2000; Toews and Subramanyam, 2003; Flinn et al., 2004; Toews et al., 2005; Fields, 2006). R. dominica is a secondary grain pest, in which the first instar larvae have been observed to enter grain through the intact kernel (Arthur, 1999) and cannot be removed from the grain through normal cleaning procedures (Flinn, 1998).

Number of organophosphorous (OP) insecticides have been and are being used against stored grains pests which have resulted in the development of severe resistance in many insect species including lesser grain borer (Champ and Dyte, 1977; Haliscak and Beeman, 1983; Zettler and Cuperus, 1990; Khan et al., 1995; Kotze and Wallbank, 1996; Ma et al., 2004; Syed et al., 2005).

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developed resistance (Bengston et al., 1980, 1983, 1987). Deltamethrin along with piperonyl butoxide (PBO) resulted in 89% reversal in deltamethrin resistance in just one generation in larvae of yellow fever mosquito, *Aedes aegypti*, which after 15 generations returned to the original level (Kumar et al., 2002). Nayak et al. (2003) also reported similar effects of mixture of OP with carbaryl on three psocid species.

The objective of this study was to determine the toxicity of mixtures of malathion and deltamethrin in different ratios against *R. dominica* to identify the most effective dosage for the control of this pest.

**MATERIALS AND METHODS**

*Beetle culture and its maintenance*

Six strains of *R. dominica* were collected from godowns of different regions of Pakistan like Chichawatni (C), Karachi (K), Wazirabad (W), Sialkot (S), Lahore (L), and Multan (M) in the form of original cultures. These strains were maintained in sterilized jam bottles covered with muslin cloth in a culture room at 30±2°C with relative humidity of 65±5%. Beetles were fed wheat after fumigation with phosphine for 24 hours. Newly hatched adult beetles collected 43±2 days after egg laying were used in the present study (Anonymous, 1974).

*Insecticides*

Technical grades of malathion [diethyl (dimethoxyphosphinothioylthio) succinate] 57EC and deltamethrin [(S)-α-cyano-3-phenoxybenzyl ester; decis; K-othrine], 25mg/kg were obtained from the Agricultural Chemical Group of FMC Corporation, Lahore, Pakistan.

*Estimation of LC₅₀*

Using serial dilutions of malathion, deltamethrin and their mixtures in acetone, LC₅₀ was determined. Different concentrations of insecticides alone and their combinations in triplicate were applied to glass Petri plates (dia. mm, 130 cm²) by residual film method. These concentrations were prepared by dissolving calculated amount of insecticides in 10 ml of acetone.

Two sets of mixtures of malathion and deltamethrin were prepared (Table I). In mixtures of set I (1-5) concentration of malathion was kept constant, whereas, concentration of deltamethrin was changed. In set II (6-8) combinations, concentration of malathion was varied, whereas, concentration of deltamethrin was kept constant.

<table>
<thead>
<tr>
<th>Mixture No.</th>
<th>Ratio of mixtures</th>
<th>Quantities mixed malathion+deltamethrin (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10:0.5</td>
<td>40 + 2</td>
</tr>
<tr>
<td>2</td>
<td>10:1.0</td>
<td>40 + 4</td>
</tr>
<tr>
<td>3</td>
<td>10:1.5</td>
<td>40 + 6</td>
</tr>
<tr>
<td>4</td>
<td>10:2.0</td>
<td>40 + 8</td>
</tr>
<tr>
<td>5</td>
<td>10:2.5</td>
<td>40 + 10</td>
</tr>
<tr>
<td>6</td>
<td>9.5:2.0</td>
<td>38 + 8</td>
</tr>
<tr>
<td>7</td>
<td>9.0:2.0</td>
<td>36 + 8</td>
</tr>
<tr>
<td>8</td>
<td>8.5:2.0</td>
<td>34 + 8</td>
</tr>
</tbody>
</table>

About 9 serial dilutions viz., 256 ppm, 128 ppm, 64 ppm, 32 ppm, 16 ppm, 8 ppm, 4 ppm, 2 ppm and 1 ppm were made to estimate LC₅₀ of each insecticide and their mixtures. 1.3 ml of these dilutions were applied in the centre of glass Petri plates (in triplicate) with the help of glass pipette. To spread the insecticides uniformly the Petri plates were rotated manually. The acetone was allowed to evaporate after which ten healthy beetles were placed in each Petri plate and covered. Three control Petri plates were also prepared for each set of mixtures and individual insecticides. The control plates contained acetone only with 10 healthy adult beetles. Beetles were checked by using camel hair brush for mortality after 48 hours. They were considered dead if on touching with brush they did not show any movement. Lloyd method (1969) was used for counting the mortality. LC₅₀ was calculated by computerized probit analysis (Finney, 1971).

**RESULTS AND DISCUSSION**

*Toxicity of malathion*

Table II shows the toxicity of malathion and
deltamethrin alone and in combination, on six different strains of *R. dominica*. C strain was found to be the most resistant (LC$_{50}$ 115.5 ppm) and M Table II.- Comparison of the LC$_{50}$ (in ppm) of malathion and deltamethrin administered alone and in mixtures in different ratios against different strains of *Rhyzopertha dominica*.

<table>
<thead>
<tr>
<th>Insecticides (Dose)</th>
<th>Strains of <em>Rhyzopertha dominica</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chichawatni (C)</td>
</tr>
<tr>
<td>Malathion</td>
<td>115.50</td>
</tr>
<tr>
<td>Deltamethrin</td>
<td>5.00</td>
</tr>
<tr>
<td>Malathion:Deltamethrin Mix. (10:0.5)</td>
<td>12.08</td>
</tr>
<tr>
<td>Malathion:Deltamethrin Mix. (10:1)</td>
<td>24.94</td>
</tr>
<tr>
<td>Malathion:Deltamethrin Mix. (10:1.5)</td>
<td>6.32</td>
</tr>
<tr>
<td>Malathion:Deltamethrin Mix. (10:2)</td>
<td>5.40</td>
</tr>
<tr>
<td>Malathion:Deltamethrin Mix. (10:2.5)</td>
<td>14.52</td>
</tr>
<tr>
<td>Malathion:Deltamethrin Mix. (9.5:2)</td>
<td>9.77</td>
</tr>
<tr>
<td>Malathion:Deltamethrin Mix. (9:2)</td>
<td>6.09</td>
</tr>
<tr>
<td>Malathion:Deltamethrin Mix. (8.5:2)</td>
<td>23.27</td>
</tr>
</tbody>
</table>

strains the least resistant (LC$_{50}$ 12.40 ppm) against malathion. The gradation followed by different strains C > W > K > L > S > M. Researches in the past shows that number of OP including malathion resulted in the development of severe resistance in many insect species including lesser grain borer). (Badmin, 1990; Rossiter *et al.*, 2001; Li *et al.*, 2005). Only freshly prepared malathion 2ppm-8ppm produced 100% mortality in adults of hairy fungus beetle, *Typhae stercorea* (Tigar and Pinniger, 1996). Guedes *et al.*, 1996, reported the failure of many other OP protectants *e.g.*, chlorpyrifos-methyl and primiphos-methyl to control the Brazilian and U.S. populations of *R. dominica*.

**Toxicity of deltamethrin**

Strain M of *R. dominica* was found to be most resistant (LC$_{50}$ 10.55 ppm) and L strain was most sensitive (LC$_{50}$ 2.83 ppm) to deltamethrin. The gradation followed by different strains was M > S > W > K > C > L. Comparatively deltamethrin was more toxic when its LC$_{50}$ values are compared with those of malathion (115.5 and 12.4ppm). Arthur (1997) has also reported high toxicity of deltamethrin dust (0.05%) to *R. dominica* and *T. castaneum*. It is found more efficient with 0.25ppm against *S. oryzae* than other pyrethroids (Athanassiou *et al.*, 2004). High sensitivity to pyrethroids, deltamethrin and esfenvalerate, has also been determined in aquatic insects larvae (Beketov, 2004). Deltamethrin and cypermethrin have been shown to be inefficient in mosquito control (Enayati and Hemingway, 2006). Development of severe resistance to pyrethroids including deltamethrin has been reported in granary weevil *S. granarius* (L.) (Curculionidae) adults (Kljajic and Peric, 2006).

**Toxicity of mixtures of malathion and deltamethrin**

Table II also shows the effect of different mixtures of two insecticides (malathion and deltamethrin) on lesser grain borer. Mixture 10:0.5 was found to be quite ineffective to all tested strains as its LC$_{50}$ values are quite high (12.08-18.80 ppm) when compared with those of deltamethrin alone (2.83-10.55 ppm). The order of gradation of resistance shown by all the strains for this mixture was K > W > M > L > S > C.

For mixture 10:1 the different strains followed the gradation C > W > M > S > K > L. This mixture is effective for K, S and M strain with LC$_{50}$ values 4.71, 5.33 and 8.38 ppm, respectively. For mixture 10:1.5 it was K > M > S > C > L > W. It is effective for W and M strain with LC$_{50}$ values 4.52 and 8.25 ppm, respectively. For mixture 10:2 it was L > M > K > W > S > C with LC$_{50}$ values ranging from 5.40-19.05 ppm. It is ineffective for each of the six strains. For mixture 10:2.5 it was M > S > K > C > L > W with LC$_{50}$ values ranging from 8.24 -19.61 ppm. It is ineffective, too. Therefore, the order of effectiveness of the set I combinations mixtures is
10:1 > mixture 10:1.5 > mixture 10:0.5 = mixture 10:2 = mixture 10:2.5.

Treating the six strains of lesser grain borer with set II combinations the mixture 9.5:2 was quite ineffective with LC\textsubscript{50} values ranging between 9.77-52.10 ppm. Mixture 9:2 was very effective for W and M strain with LC\textsubscript{50} values of 3.13 and 5.27 ppm, respectively. Mixture 8.5:2 was effective for only M strain (LC\textsubscript{50} 7.80 ppm). The order of effectiveness of the set II combinations is mixture 9:2 > mixture 8.5:2 > mixture 9.5:2.

Of the first set of combinations, mixture 10:1 is effective for K, S and M strains. Mixture 10:1.5 and mixture 9:2 from set II combinations with comparatively low LC\textsubscript{50} values proved to be the most effective for the W and M strains of the lesser grain borer.

The results of the present study is in accordance with the findings of Shakoori and Saleem (1989) on Tribolium castaneum and by Ali et al. (2003) on R. dominica adults, who concluded that OP in combination with pyrethroid is much more effective than when administered alone. In some other studies, pyrethroid (resmethrin and bioresmethrin) combined with chlorpyrifos-methyl (OP) and cyfluthrin (pyrethroid) plus piperonyl butoxide plus chlorpyrifos-methyl proved very effective against lesser grain borer (Arthur, 1992, 1994).

Considering all the effective combinations together, the efficacy of the mixtures in descending order for K and S strains is: mixture 10:1 > mixture 10:1.5 > mixture 9:2 for W and M strain, mixture 9:2 > mixture 10:1.5 > mixture 10:1.

Previously the effectiveness of organophosphate-pyrethroid combinations against R. dominica and Sitophilus oryzae has also been reported by Pereira et al. (1997) and Pinto et al. (1997) where a mixture of fenitrothion, deltamethrin and piperonyl butoxide caused 100% mortality in these beetles. The mixture of bifenthrin, PBO and chlorpyrifos prevented R. dominica and other beetles from producing live progeny (Daglish et al., 2003). Ahmad (2004) also established the effectiveness of OP-pyrethroid combinations against Helicoverpa armigera. According to Haung and Subramanyam (2005) a mixture of primiphos-methyl (OP) and synergized pyrethrins was not superior to primiphos-methyl alone against the five insect pests including R. dominica.

Overall results of this study conclude that OP-pyrethroid mixtures have more powerful and beneficial control over this beetle than when these insecticides are used alone. Furthermore, mixture 10:1, mixture 10:1.5 and mixture 9:2 with comparatively low LC\textsubscript{50} values were found to be the most effective against R. dominica. Therefore, controlling resistant insects with insecticide mixtures is strongly recommended.

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