PEST MANAGEMENT

Flight Activity of *Sitophilus oryzae* (L) and *Sitophilus zeamais* Motsch (Coleoptera: Curculionidae) and its Relationship with Susceptibility to Insecticides

**JAVIER A VÁSQUEZ-CASTRO¹, GILBERTO C DE BAPTISTA², LUIZ R P TREVIZAN², CASIMIRO D GADANHA Jr³**

¹Dep. de Entomologia, Univ. Nacional Agraria La Molina, Av. La Universidad s/n, apartado 456, Lima 100, Peru; jaque@lamolina.edu.pe; ²Dep. de Entomologia, Fitopatologia e Zoologia Agrícola, ³Dep. de Engenharia Rural, Escola Superior de Agricultura “Luiz de Queiroz”, USP, 13418-900, Piracicaba, SP, Brazil; gc baptis@esalq.usp.br, lp trevi@esalq.usp.br, cd gadanh@esalq.usp.br


**ABSTRACT** - Insect-pest mobility can influence insect susceptibility to the insecticides used to control them. The objective of this work was to evaluate the flight activity of *Sitophilus oryzae* (L) and *Sitophilus zeamais* Motsch populations reared on corn and wheat grains, and its relationship with insecticide susceptibility. Unsexed adult insects with ages between 10 and 20 days were placed on a plastic tray. A 40-watt incandescent light bulb was positioned at a 50 cm height relative to the tray. Flight activity was evaluated during 30 min. In the LC₅₀ estimation bioassays, the insects were exposed to dry residues of the organophosphorus insecticide fenitrothion and of the pyrethroid insecticide esfenvalerate on the internal surface of glass vials. Mortality was evaluated 24h after installation of the experiments. *Sitophilus zeamais* showed greater flight activity when compared with *S. oryzae*; likewise, insects reared on corn had greater flight activity than those reared on wheat. *Sitophilus oryzae* was less susceptible to the insecticides studied than *S. zeamais*. Adults reared on wheat were more susceptible to the insecticides than those reared on corn. This study demonstrates that the lower flight activity of *S. oryzae* is related to its greater tolerance to insecticides.

**KEY WORDS:** Stored grain, chemical control, tolerance, resistance, gene flow

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Stored cereals are attacked by pests that cause both quantitative (Nyambo 1993) and qualitative losses (Hagstrum *et al* 1999). According to data estimated by FAO and by the Brazilian Ministério da Agricultura, Pecuária e Abastecimento, these losses amount to 10% of the grain yield in Brazil (Beskow & Deckers 2002).
Due to its high biotic potential and to the fact that infestations start in the field and are brought into the store, *Sitophilus oryzae* (L) and *Sitophilus zeamais* Motsch are considered the most destructive pests that attack stored corn and wheat in Brazil (Gallo et al. 2002). Although both species can develop on both types of grain, *S. oryzae* has a marked preference for wheat, while *S. zeamais* strongly prefers corn (Rossetto 1969, Athié & Paula 2002).

Both species were reared on insecticide-free corn and wheat (*Z. mays* L) and *S. oryzae* (*S. oryzae*) and *S. zeamais* (*S. zeamais*) specimens were kept in culture in these laboratories for over 20 years in the absence of selective pressure of insecticides. Therefore, they were considered reference susceptible lines. Both species were reared on insecticide-free corn and wheat grains, and their relationship with insecticide susceptibility.

**Material and Methods**

**Insects.** *Sitophilus oryzae* and *S. zeamais* specimens were obtained from the insect rearing laboratories at the Centro de Energia Nuclear na Agricultura – CENA/USP, in Piracicaba, SP and from the Centro Nacional de Pesquisa de Milho e Sorgo – CNPMS/EMBRAPA, in Sete Lagoas, MG, respectively. The populations of both *S. oryzae* and *S. zeamais* were kept in culture in these laboratories for over 20 years in the absence of selective pressure of insecticides. Therefore, they were considered reference susceptible lines. Both species were reared on insecticide-free corn and wheat grains until installation of the experiments.

**Flight activity.** Unsexed 10-20 day old adults were placed on plastic trays (40 cm long, 25 cm wide, 7 cm high). A 40-watt incandescent light bulb was positioned at 50 cm above the tray, and flight activity was evaluated for 30 min. Flight was defined as the insect movement in the air, regardless of the distance traveled. Individuals that engaged into flight activity were immediately eliminated and immersed in ethanol. Four replicates each containing 25 insects were installed for each rearing substrate (corn and wheat). The experiments were conducted between 3 p.m. and 5 p.m., the period in which the species under study have their most intense flight activity (Giles 1969, Taylor 1971). Temperature and relative humidity during the tests were 25 ± 1°C and 75%, respectively. Because the variable response of the experiment had a binomial distribution, the data were analyzed by means of logistic regression, using the SAS (1999) logistic procedure.

**LC50.** Fenitrothion (99.1% a.i.) and esfenvalerate (100% a.i.) analytical standards were used (Iharabras S.A., Sorocaba, SP, Brazil). The bioassays to estimate LC50 were adapted from studies on resistance to insecticides of *Rhyzopertha dominica* (F) (Coleoptera: Bostrichidae) (Guedes et al. 1996). Unsexed 10-20-day old adults were exposed to dry residues of the insecticides on the internal surface of glass vials (2.3 cm diameter × 4 cm height). Five ml of the insecticidal solutions were transferred to the vials and then evaporated by moving air previously dried through a blue silica gel desiccant filter. Afterwards, 25 individuals were placed inside the vials and maintained under controlled conditions (25 ± 1°C temperature and 74% RH). In order to prevent the insects from leaving the treated area, a fine layer of liquid vaseline was spread on the border between the treated and untreated areas of the vial. Mortality was evaluated 24h after installation of the experiments. Still individuals, deemed incapable of moving even when encouraged by an incandescent light source placed a few centimeters from them were considered to be dead. Each bioassay consisted of five or six concentrations, with four replicates per concentration. A control treatment was also included in which the solvent alone (acetone) was applied, with replicates. The concentration-mortality data were submitted to Probit analysis (LeOra Software 1987).

**Results and Discussion**

**Flight activity.** The complete model, in which the effects of the main pest species, the grain type and the interaction between them were observed, provided a good fit of data. The residual deviance was 3.80 and the residual X2 statistic was 4.02 - both non-significant (P > 0.98) when compared with the 12 degrees of freedom of the residue. There was a significant effect (P < 0.01) for the main pest species and grain type effects, but not for the interaction between these two factors (P = 0.0731), indicating that the pest species effect is independent from grain type and vice versa (Table 1). *Sitophilus zeamais* had greater flight activity than *S. oryzae* (Fig 1). Likewise, insects reared on corn had greater flight activity than those reared on wheat. The behavioral differences observed between both species suggest *S. zeamais* has a greater natural dispersal capacity, with a potential to migrate from the storage areas to the field and vice versa (Giles & Ashman 1971, Chesnut 1972). Such migration...
encourages the infestation of grains even before they are harvested, and may thus cause significant losses during the storage period. On the other hand, migration also encourages crosses between populations from storage facilities (either family-owned or commercial), where they are exposed to different levels of selection pressure by insecticides and field-inhabiting populations, which do not have contact with these chemical products. Consequently, high gene flow might dilute resistance, facilitating the chemical control of this pest species. The contrary occurs with *S. oryzae* which, because of its reduced flight activity, remains restricted to the storage environment, where a constant selection pressure by insecticides might encourage the development of resistance.

An apparent stimulating effect of the corn kernel was observed on the flight activity of both species, meaning that infestations in the field may occur by migration of populations from stores that contain corn. When *S. oryzae* was reared on corn grains it showed a similar flight activity as *S. zeamais* reared on wheat grains. Under laboratory conditions, both species can be reared on both types of grains; but under storage conditions there is a marked preference of *S. oryzae* for wheat and of *S. zeamais* for corn (Adhi & Paula 2002). In this respect, Rossetto (1969) evaluated corn samples collected in the State of São Paulo and found 169 samples infested with *S. zeamais*, 11 samples infested with both *S. oryzae* and *S. zeamais*, and a single sample infested with *S. oryzae*. When both species infest the same mass of grains, competition between them results in the elimination of *S. oryzae* in corn and of *S. zeamais* in wheat (Birch 1954 apud Coombs & Porter 1986). Consequently, the infestation in corn in the field will almost exclusively occur due to *S. zeamais*. Many studies have shown that *S. zeamais* is the only species in this genus that infests corn in the field (Chesnut 1972, Hodges et al. 1998). Similarly, a greater flight activity of this species has been reported inside stores (Likhayo & Hodges 2000) and under laboratory conditions (Coombs & Porter 1986).

**LC₅₀** The mortality in the control treatment was about 5%. Both species were significantly more susceptible to fenitrothion than to esfenvalerate. For fenitrothion, *S. oryzae* was slightly more tolerant than *S. zeamais*; for esfenvalerate, however, the difference in tolerance between the species was much broader (Table 2). One explanation for these results is the great gene flow that occurs in *S. zeamais*, which might dilute resistance, and the low migration capacity of *S. oryzae*, which might favor development of this phenomenon.

Through time, this trait seems to have encouraged greater tolerance to insecticides in *S. oryzae* than in *S. zeamais*. In this respect, greater tolerance of *S. oryzae* to organophosphorus compounds (Samson & Parker 1989) and greater genetic variability of *S. zeamais* (Grenier et al. 1994) have been reported. Although several studies have demonstrated a high effectiveness of organophosphorus compounds to control *Sitophilus* spp. (Collins et al. 1993, Sgarbiero et al. 2003), the resistance of Brazilian *S. oryzae* populations to this class

Table 2 Characterization of *Sitophilus oryzae* and *Sitophilus zeamais* susceptibility when reared on corn and wheat grains, to the insecticides fenitrothion and esfenvalerate by means of a dry film bioassay.

<table>
<thead>
<tr>
<th>Species / grain type</th>
<th>LC₅₀ μg A.I./ml</th>
<th>Confidence interval (95%)</th>
<th>Slope coefficient ± standard error</th>
<th>X²</th>
<th>D.F.</th>
<th>P &gt; 0.05</th>
<th>Heterogeneity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fenitrothion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>S. oryzae / corn</em></td>
<td>0.17</td>
<td>0.15 – 0.19</td>
<td>5.77 ± 0.43</td>
<td>5.93</td>
<td>3</td>
<td>1.98</td>
<td></td>
</tr>
<tr>
<td><em>S. oryzae / wheat</em></td>
<td>0.09</td>
<td>0.06 – 0.10</td>
<td>3.74 ± 0.39</td>
<td>5.70</td>
<td>3</td>
<td>1.90</td>
<td></td>
</tr>
<tr>
<td><em>S. zeamais / corn</em></td>
<td>0.08</td>
<td>0.07 – 0.10</td>
<td>4.69 ± 0.59</td>
<td>10.17</td>
<td>3</td>
<td>3.39</td>
<td></td>
</tr>
<tr>
<td><em>S. zeamais / wheat</em></td>
<td>0.06</td>
<td>0.05 – 0.07</td>
<td>10.07 ± 0.98</td>
<td>10.88</td>
<td>3</td>
<td>3.63</td>
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<tr>
<td><strong>Esfenvalerate</strong></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><em>S. oryzae / corn</em></td>
<td>3.54</td>
<td>2.84 – 4.94</td>
<td>2.39 ± 0.24</td>
<td>3.43</td>
<td>3</td>
<td>1.14</td>
<td></td>
</tr>
<tr>
<td><em>S. oryzae / wheat</em></td>
<td>1.80</td>
<td>1.57 – 2.08</td>
<td>1.86 ± 0.17</td>
<td>0.88</td>
<td>4</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td><em>S. zeamais / corn</em></td>
<td>0.26</td>
<td>0.20 – 0.34</td>
<td>2.17 ± 0.16</td>
<td>8.99</td>
<td>4</td>
<td>2.25</td>
<td></td>
</tr>
<tr>
<td><em>S. zeamais / wheat</em></td>
<td>0.30</td>
<td>0.27 – 0.34</td>
<td>2.18 ± 0.16</td>
<td>3.95</td>
<td>4</td>
<td>0.99</td>
<td></td>
</tr>
</tbody>
</table>
of insecticides was demonstrated (Pacheco et al. 1993). This situation is opposed to that observed in *S. zeamais*, where only a slight resistance to chlorpyrifos methyl was found until recently (Ribeiro et al. 2003). Similar results were obtained by Samson & Parker (1989) and Vásquez-Castro (2006), who recorded better control of *S. zeamais* than of *S. oryzae* when organophosphorus insecticides were used. Although esfenvalerate has never been used against the populations under study, it was less toxic than fenitrothion. This was possibly due to cross resistance with other pyrethroids such as deltamethrin and with DDT, an insecticide much used in the past to control pests in stores, since both DDT and pyrethroids share the same mechanism of action. This phenomenon was verified in *Sitophilus granarius* (L) by Pickett (1980), in *S. oryzae* by Heather (1986) and in *S. zeamais* by Guedes (1993).

The insects reared on wheat were more susceptible to the insecticides than those reared on corn, except for *S. zeamais* exposed to esfenvalerate, in which both populations showed the same degree of susceptibility. Thus, the *S. oryzae* population reared on corn was two-fold more tolerant to fenitrothion and esfenvalerate than the population reared on wheat, while the *S. zeamais* population reared on corn was 1.3-fold more tolerant to fenitrothion than the one reared on wheat. These results demonstrate the influence of food type on the susceptibility of pests to insecticides; therefore, it is important to take this factor into consideration in the establishment of insecticide resistance management programs for stored grain insect pests, since apparently different doses should be used initially to treat corn and wheat.

In conclusion, *S. zeamais* shows greater flight activity than *S. oryzae* and therefore is more susceptible to the insecticides used in stored grain protection. On the other hand, insects reared on corn show greater tolerance to the insecticides than those reared on wheat.

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**References**


Pacheco I A, Sartori M R, Bolonhezi S (1993) Resistência ao malatión, pirimifós-metílico e ao fenitrothion em coleopteros-


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