N = 32). One female mated the day she molted and was placed in the observation chambers. All females had mated by 8 days after the final molt.

The data presented here are similar to data presented from a single observation on 3 female G. integer where females also mated soon after the adult molt (Sakaluk & Cade 1980). Female Teleogryllus commodus (Walker) mate within hrs of the adult molt (Loher & Edson 1973), and female house crickets, Acheta domestica (L.) become sexually receptive approximately 2 days after the adult molt (Sakaluk 1982).

REFERENCES CITED


----

COMPARATIVE TOXICITY OF FIVE BACILLUS THURINGIENSIS STRAINS AND FORMULATIONS AGAINST SPODOPTERA EXIGUA (LEPIDOPTERA: NOCTUIDAE)

WILLIAM J. MOAR AND JOHN T. TRUMBLE
Department of Entomology, University of California
Riverside, California 92521

The beet armyworm, Spodoptera exigua (Hübner), is a polyphagous noctuid that is a primary pest on agricultural crops in the United States and Mexico (Metcalf et al. 1962, Alvarado-Rodriguez 1987). Low economic thresholds, and apparent resistance to pesticides (Poe et al. 1973, Meinke & Ware 1978) have increased chemical use, leading to higher control costs and harmful effects on beneficial insects suppressing other pest species such as the Liriomyza spp. leafminers (Trumble 1985).

Insecticides containing Bacillus thuringiensis subsp. kurstaki (Berliner) have been registered since 1961, but recommended field rates in many vegetable crops result in unsatisfactory S. exigua control (Wyman & Oatman 1977). B. thuringiensis subsp. kurstaki has proven to be virtually non-toxic to key parasite species of Liriomyza leafminers (Carson et al. 1987), and therefore would be a good insecticide to use in an integrated pest management system.
An approach to resolving this problem of B. thuringiensis field efficacy has been the recent commercial release of the NRD-12 isolate of B. thuringiensis subsp. kurstaki, marketed as Javelin, which has improved activity against Spodoptera species. Moar et al. (1986) also demonstrated that the commercial wettable powder formulation of Javelin was 3-4 times more toxic to S. exigua in diet incorporation studies than Dipel 2X. Since various Spodoptera spp. cause economic damage on numerous crops, there is increasing interest in developing more efficacious B. thuringiensis products. Therefore, the purpose of this study was to determine the toxicity of new commercial formulations of B. thuringiensis to S. exigua.

Wettable powder/geminate test materials included Dipel 2X containing the HD-1 isolate of B. thuringiensis subsp. kurstaki with 32,000 international units (IU)/mg, ABG-6218 (Abbott Laboratories), and SAN 415 WG 354 (Sandoz Corp.). Flowable liquid test materials included SAN 415 SC 353 (commercially available as Javelin), and SAN 415 SC 363 (Sandoz Corp.).

Bioassays with B. thuringiensis were conducted with seven-eight concentrations plus a control for individual treatments. Concentration ranges for wettable powder/ granule compounds (μg/ml diet) tested were as follows: Dipel 2X; 25-800; ABG-6218; 20-320; SAN 415 WG 354; 5-80. Suspensions were made by adding materials to 50 ml 0.1% Tween 80 solution. Suspensions were chilled to 10°C and suspended for 30 seconds with a sonic dismembrator. Concentration ranges for flowable liquid compounds (μg/ml diet) tested were as follows: SAN 415 SC 353; 0.05-0.70; SAN 415 SC 363; 0.02-0.12. Suspensions were made by adding materials to an aqueous 0.1% Tween 80 solution to produce 50 ml. Suspensions were chilled to 10°C and vortexed for one min. Controls consisted of 50 ml of an aqueous 0.1% Tween 80 solution.

Each concentration was added to artificial diet (Patana 1969), mixed, poured into 30 ml plastic cups, and a single neonate S. exigua (0-4 h old) placed in each cup as described by Moar et al. (1986). The neonate S. exigua larvae used in all tests were taken from a stock culture which was maintained on the same artificial diet as described previously at 27 ± 1°C, and a photoperiod of 16:8 (L:D). This temperature and photoperiod also were used in the bioassays. At least 30 insects were tested with each concentration; tests with each concentration were replicated five-six times. Larval mortality was assessed at 7 days in all treatments.

Data were analyzed using the Proc Probit procedure (SAS Institute 1985) after correction for control mortality with Abbott’s (1925) formula, and then judged for suitability as described by Vaudekar & Dhunia (1982). Remaining values were pooled. Control mortality was ≤ 10%.

The LC_{50} for SAN 415 WG 354 (26.4 μg/ml diet) and ABG-6218 (55.1 μg/ml diet) were 7.0 and 3.35 times lower than the LC_{50} for Dipel 2X (184 μg/ml diet) (Table 1). The LC_{50} value for Dipel 2X is consistent with a previous report indicating 50% mortality at 196 μg/ml (Moar & Trumble 1987). Comparisons of the toxicities of the liquid formulations determined that the LC_{50} value for SAN 415 SC 363 (0.05 μg/ml diet) was ca. 3.0 times lower than for SAN 415 SC 353 (0.15 μg/ml diet) (Table 1). Thus, these new B. thuringiensis products are more efficacious in the laboratory against S. exigua than the commercially available Dipel 2X and Javelin. However, outdoor testing of these products must be conducted to determine if similar results will occur under the relatively more adverse environmental conditions associated with production agriculture in the field.

We thank K. Kamrath for her assistance in bioassays. This research was supported in part by the California Celery Research Advisory Board, the Western Regional Pesticide Impact Assessment Program, the California Department of Food and Agriculture, Abbott Laboratories, and Sandoz Corporation.
### TABLE 1. Lethal Concentrations of Various Wettable Powder (μg/ml Diet) and Flowable Liquid (μl/ml Diet) Formulations of Bacillus thuringiensis Against Neonate S. exigua.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>Slope ± SEM</th>
<th>LC₉₀ (95% FL)</th>
<th>LC₉₀ (95% FL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid formulations (granule and wettable powders)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dipel 2X</td>
<td>1200</td>
<td>1.82 ± 0.13</td>
<td>184 (154-220)</td>
<td>950 (719-1381)</td>
</tr>
<tr>
<td>ABG-6218</td>
<td>1440</td>
<td>2.06 ± 0.14</td>
<td>55.1 (48.9-61.2)</td>
<td>231 (198-280)</td>
</tr>
<tr>
<td>SAN 415 WG 354</td>
<td>1220</td>
<td>2.60 ± 0.14</td>
<td>26.4 (24.4-28.4)</td>
<td>82.1 (75.1-94.2)</td>
</tr>
<tr>
<td>Liquid formulations (soluble concentrates)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAN 415 SC 353</td>
<td>1220</td>
<td>2.63 ± 0.13</td>
<td>0.15 (0.13-0.16)</td>
<td>0.45 (0.40-0.51)</td>
</tr>
<tr>
<td>SAN 415 SC 383</td>
<td>1060</td>
<td>3.00 ± 0.40</td>
<td>0.06 (0.048-0.062)</td>
<td>0.12 (0.097-0.152)</td>
</tr>
</tbody>
</table>

*Number of total insects assayed from 7-8 concentrations and 5-6 replicates.

### REFERENCES CITED


