Reprinted from *Florida Entomologist*, Volume 73, Number (1), March, 1990.

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/granule 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 (μl/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 Vandekar & Dulmage (1982). Remaining values were pooled. Control mortality was ≤ 10%.

The LC_{50}'s 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 μ/ml diet (Moar & Trumble 1987). Comparisons of the toxicities of the liquid formulations determined that the LC_{50} value for SAN 415 SC 363 (0.05 μ/ml diet) was ca. 3.0 times lower than for SAN 415 SC 353 (0.15 μ/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*.

Treatment	n[a]	Slope ± SEM	LC_{50} (95% FL)	LC_{90} (95% Fl)
		Solid formulations (granule and wettable powders)		
Dipel 2X	1200	1.82 ± 0.13	184 (154-220)	950 (719-1381)
ABG-6218	1440	2.06 ± 0.14	55.1 (48.9-61.2)	231 (198-280)
SAN 415 WG 354	1220	2.60 ± 0.14	26.4 (24.4-28.4)	82.1 (73.1-94.2)
		Liquid formulations (soluble concentrates)		
SAN 415 SC 353	1220	2.63 ± 0.13	0.15 (0.13-0.16)	0.45 (0.40-0.51)
SAN 415 SC 363	1050	3.90 ± 0.40	0.05 (0.048-0.062)	0.12 (0.097-0.152)

[a]Number of total insects assayed from 7-8 concentrations and 5-6 replicates.

REFERENCES CITED

ABBOTT, W. S. 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 265-267.

ALVARADO-RODRIGUEZ, B. 1987. Parasites and disease associated with larvae of beet armyworm *Spodoptera exigua* (Lepidoptera: Noctuidae), infesting processing tomatoes in Sinaloa, Mexico. Florida Entomol. 70(4): 444-449.

CARSON, W. G., J. T. TRUMBLE, AND H. NAKAKIHARA. 1987. Effect of insecticides on lepidopterous larvae and leafminers on celery. Insect. Acaric. Tests 12: 118.

MEINKE, L. S., AND G. W. WARE. 1978. 1978. Tolerance of three beet armyworm strains in Arizona to methomyl. J. Econ. Entomol. 71: 645-646.

METCALF, C. L., W. P. FLINT, AND R. L. METCALF. 1962. Destructive and useful insects. Their habits and control. McGraw-Hill, New York.

MOAR, W. J., W. L. A. OSBRINK, AND J. T. TRUMBLE. 1986. Potentiation of *Bacillus thuringiensis* var. *kurstaki* with thuringiensin on beet armyworm (Lepidoptera: Noctuidae). J. Econ. Entomol. 79: 1443-1446.

MOAR, W. J., AND J. T. TRUMBLE. 1987. Toxicity, joint action, and mean time of mortality of Dipel 2X, avermectin B1, neem and thuringiensin against beet armyworm (Lepidoptera: Noctuidae). J. Econ. Entomol. 80: 588-592.

PATANA, R. 1969. Rearing cotton insects in the laboratory. U.S. Dep. Agric. Prod. Res. Rep. 108.

POE, S. L., G. L. CRANE, AND D. COOPER. 1973. Bionomics of *Spodoptera exigua* (Hub.), the beet armyworm, in relation to floral crops. Proc. Trop. Reg. Am. Soc. Hortic. Sci. 17: 389-396.

SAS INSTITUTE. 1985. SAS user's guide: statistics, version 5 ed. SAS Institute, Gary, NC.

TRUMBLE, J. T. 1985. Integrated pest management of *Liriomyza trifolii*: influence of avermectin, cyromazine, and methomyl on leafminer ecology in celery. Agric. Ecosyst. Environ. 12: 181-188.

VANDEKAR, M., AND H. T. DULMAGE. 1982. Guidelines for production of *Bacillus thuringiensis* H-14. United Nations Developing Program/World Bank/ World Health Organization, Geneva.

WYMAN, J. A., AND E. R. OATMAN. 1977. Yield responses in broccoli plantings sprayed with *Bacillus thuringiensis* at various lepidopterous larval density treatment levels. J. Econ. Entomol. 70: 821-824.