APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Oct. 1976, p. 508-510 Vol. 32, No. 4
 Printed in U.S.A.

Commercial Formulations of *Bacillus thuringiensis* for Control of Indian Meal Moth

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Received for publication 23 April 1976

Doses of four commercial formulations and one experimental formulation of *Bacillus thuringiensis* Berliner were mixed with the diet used to rear colonies of the Indian meal moth *Plodia interpunctella* (Hübner). Indian meal moth eggs were introduced to the treated diet, and the resultant adult emergence was tabulated. The experimental formulations ranked as follows in efficacy in controlling the Indian meal moth: Dipel (50% lethal concentration [LC_{50}], 25 mg/kg) > Bactospeine WP (LC_{50}, 100 mg/kg) > Thuricide (LC_{50}, 150 mg/kg) > IMC 90007 (LC_{50}, 180 mg/kg) > Bactospeine Flowable (LC_{50}, 440 mg/kg).

The Indian meal moth *Plodia interpunctella* (Hübner), a serious pest of stored grain and processed cereal products, is becoming resistant to malathion (1). Since no insecticides have yet been approved to replace malathion as a protectant for stored grain, other materials are being investigated, among them microbial insecticides.

Previous investigators (2, 3) showed that laboratory preparations of *Bacillus thuringiensis* Berliner were lethal to Indian meal moth larvae and demonstrated the efficacy of similar preparations when applied to stored grain. However, to my knowledge, no comparison has been made of the efficacy of available commercial bacterial products for such use. The purpose of this study was to establish the relative efficacy against the Indian meal moth of *B. thuringiensis* currently marketed for control of pest insects on field crops and of one experimental formulation.

MATERIALS AND METHODS

The four commercial formulations were Dipel, a product of Abbott Laboratories; Thuricide, a product of Sandoz-Wander, Inc; and Bactospeine WP and Bactospeine Flowable, products of Rhodia, Inc. The experimental material was IMC 90007, a non-spore formulation containing 3 to 5% crystal toxin and 95 to 97% fermentation insolubles, produced by Sandoz-Wander Inc. (formerly a product of International Minerals and Chemical Corp.). The physical properties of the formulations were described by the manufacturers. Thus, Dipel was reported to contain 5.51 billion viable spores and 1.6 billion IU of potency per kg against the cabbage looper *Trichoplusia ni* (Hübner). Thuricide and IMC 90007, similar materials except that the latter is a non-spore formulation, had a potency of about 4.41 billion IU/kg against *T. ni*. However, IMC 90007 had a bacterial count of $<10^4$/g and Thuricide had a spore count of about 6.5×10^{10}/g. Each of the Bactospeine formulations had a potency of 6,000 units of activity (UA)/mg against the Mediterranean flour moth *Anagasta kuehniella* (Zeller).

Aqueous suspensions of each of the test materials were prepared at the desired concentrations and mixed vigorously with a spatula into diet in wide-mouthed, 1-quart (ca. 0.95-liter) mason jars (3). The treated diet was subdivided into 50-g lots that were placed in 1-pint (ca. 0.5-liter) mason jars. The filter paper covers were placed on the jars, and the jars were held at 25°C and 60% relative humidity. Freshly laid lots of 50 Indian meal moth eggs were removed from the insect-holding chambers at the U.S. Grain Marketing Research Center by using a small aspirator and a dissecting microscope and were placed on top of the treated diet in each jar. Percentage of mortality was calculated according to the difference between number of eggs added and number of adults that emerged. Values were corrected for mortality in the untreated diet.

Not all the materials were tested in all nine tests, but all were tested at least once. IMC 90007 was tested once (six doses; two replications). Bactospeine Flowable was tested three times (each time with six doses; two replications). Bactospeine WP was tested four times, three times with six doses (two replications) and once with seven doses (four replications). Dipel and Thuricide were tested three times, twice with six doses (two replications) and once with seven doses (four replications).

RESULTS AND DISCUSSION

The doses, equivalent levels of potency expressed as international units or units of activity, and the mortalities achieved are shown in Table 1. Dipel was effective at a lower rate than any of the other materials. IMC 90007 was only one-third to one-half as potent as Thuricide at the lower doses, although they seemed approxi-

TABLE 1. *Doses, equivalent levels of potency, and mortalities resulting from treatments with five formulations of B. thuringiensis against the Indian meal moth*

Dose (mg/kg)	Dipel		Thuricide and IMC 90007			Bactospeine		
	IU/kg[a]	% Mortality	IU/kg[a]	% Mortality		UA/kg[b]	% Mortality	
				Thuricide	IMC 90007		WP	Flowable
5	8	11	22			3		
10	16	43	44			6		
25	40	54	110	26	8	15	15	6
50	80	64	220	27	14	30	29	8
100	160	90	440	34	27	60	49	12
150	240	90	660	52	45	90	58	14
200	320	95	880	58	54	120	74	25
250	400	98	1,100	62	60	150	76	40
300	480		1,320	78		180	89	

[a] IU × 10^4 = International units against *T. ni* per kilogram of diet based on information furnished by the manufacturer.

[b] UA × 10^4 = Units of activity against *A. kuehniella* per kilogram of diet based on information furnished by the manufacturer (reference no. E61, Pasteur Institute, defines UAAk as 1,000 UA against *A. kuehniella* per mg).

TABLE 2. *Statistical analysis of data*

Formulation	LC_{50} (mg/kg)			
	Estimate	Lower	Upper	Slope
IMC 90007	174	148	212	1.64
Thuricide	140	97	249	1.24
Dipel	23	16	31	1.74
Bactospeine WP	82	64	102	1.38
Bactospeine Flowable	681	298	491,220	1.35

mately equal at the higher doses, and Bactospeine Flowable was only one-half as potent as Bactospeine WP throughout the dose range.

The data were analyzed statistically, which resulted in the 50% lethal concentrations (LC_{50}), confidence intervals, and slopes shown in Table 2.

Figure 1 shows the estimated logarithmic dose-mortality lines drawn according to the formula $Y = a + bx$ (Y = 50% on log probit; $a = Y$ intercept; b = log LC_{50}). Although the line for IMC 90007 does not seem to be parallel to the other lines, the statistical analysis indicated statistical parallelism between all five lines.

The LC_{50} for Bactospeine Flowable is highly questionable, because none of the concentrations reached 50% mortality when the LC_{50} values given above were converted to units of potency; the LC_{50} values became (× 10^4): Dipel, 40; Bactospeine WP, 60; Thuricide, 660; IMC 90007, 792; and Bactospeine Flowable, 264. When the dose-mortality lines are projected to predict an LC_{95} level, the LC_{95} for Dipel is 207 ppm, or 3.31 × 10^6 IU, and that for Bactospeine WP is 1,280 mg/kg, or 7.68 × 10^6 UA/mg.

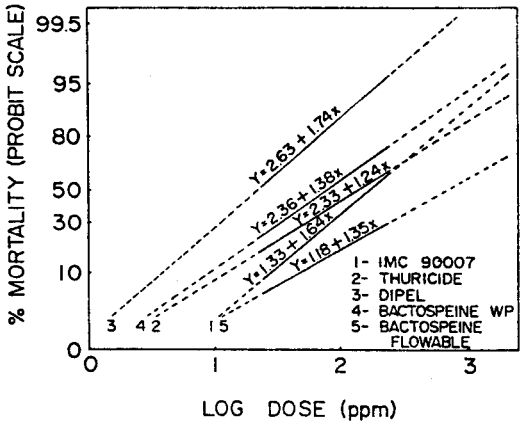

FIG. 1. *Estimated log dose-mortality lines for five formulations of B. thuringiensis against Indian meal moth.*

Thus, all five materials differ in efficacy, but all will control *P. interpunctella* when they are used at sufficiently high dosages. However, the international units against *T. ni* and the units of activity against *A. kuehniella* are apparently specific for those species. They are not predictive of efficacy against *P. interpunctella*.

ACKNOWLEDGMENT

I appreciate the helpful discussions and encouragement afforded by William H. McGaughey throughout the course of study. Gordon D. Booth, Mathematical Statistician, Agricultural Research Service, U.S. Department of Agriculture, Ames, Iowa, assisted with the statistical analysis of portions of the data.

LITERATURE CITED

1. Armstrong, J. W., and E. L. Soderstrom. 1975. Mala-

thion resistance in some populations of the Indian meal moth infesting dried fruits and tree nuts in California. J. Econ. Entomol. 68:505–507.
2. Kantack, B. H. 1959. Laboratory studies with *Bacillus thuringiensis* Berliner and its possible use for control of *Plodia interpunctella* (Hbn). J. Econ. Entomol. 52:1226–1227.
3. McGaughey, W. H. 1976. *Bacillus thuringiensis* for controlling three species of moths in stored grain. Can. Entomol. 108:105–112.