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Evaluation of Commercial Formulations of *Bacillus thuringiensis* for Control of the Indianmeal Moth and Almond Moth (Lepidoptera: Pyralidae) in Stored Inshell Peanuts[1]

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ABSTRACT

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In laboratory tests, a dust formulation of *Bacillus thuringiensis* Berliner was superior to a WP formulation in protecting farmers' stock (inshell) peanuts from Indianmeal moth, *Plodia interpunctella* (Hübner), and almond moth, *Ephestia cautella* (Walker), infestation. The WP did not completely eliminate moth emergence at rates as high as 625 mg/kg when applied as either a bulk or surface layer treatment. Efficacy of the WP was not improved by more uniform application. The dust nearly eliminated moth emergence when used as a surface layer or bulk treatment at 500 mg/kg. At equivalent dosages, the dust limited moth emergence and peanut damage to <5%, but the WP permitted ca. 23% moth emergence and peanut damage.

Bacillus thuringiensis Berliner has been extensively evaluated in laboratory and pilot scale tests and shown effective for preventing moth infestation in stored grains such as wheat and corn (McGaughey 1976, 1978,1980). However, it has been less effective on commodities such as almonds, where the shell interferes with obtaining adequate coverage of the nuts (Pinnock and Milstead 1972, Kellen et al. 1977). The laboratory study reported here was made to determine whether dust or WP formulations of *B. thuringiensis* would protect farmers' stock (inshell) peanuts from infestation by the Indianmeal moth, *Plodia interpunctella* (Hübner), and the almond moth, *Ephestia cautella* (Walker).

Materials and Methods

Four experiments were conducted, using different sizes of containers and quantities of peanuts. Experiments in glass jars were used to compare the effectiveness of the two formulations and to identify appropriate dosages for further testing. Jar tests were also used in comparing alternative means for applying the WP to the peanuts. Taller metal cylinders were used for preliminary tests to evaluate various surface layer treatment depths, as was done in earlier studies with grain (McGaughey 1976). Larger fiber drums were used in the final test to more thoroughly evaluate the effectiveness of the most promising dosage-treatment depth combination identified in the earlier tests. The two insect species were tested separately in the jar-scale tests but were combined in the larger containers due to equipment and commodity limitations. Farmers' stock peanuts, containing mostly inshell peanuts but with some loose peanuts and broken and cracked pods, were used in all tests.

To evaluate different rates of application of commercial dust and WP formulations, 500-g samples of peanuts were treated in 3.8-liter jars at rates of 125, 375, or 625 mg of Dipel WP (16,000 IU/mg)/kg, or 500, 1,500, or 2,500 mg of Top-Side Dipel dust (4,000 IU/mg)/kg. The WP formulation was suspended in water and applied at 20 ml/kg. The suspension and dust were pipetted or sprinkled on the peanuts, and the jars were rolled and shaken until incorporation appeared uniform. Four replicate jars were treated for testing against each insect species, and four jars of untreated peanuts were used as checks for each species. One hundred eggs from laboratory colonies of the Indianmeal moth and almond moth were added to the appropriate jars, and the jars were held at 25°C and 65% relative humidity (RH) until adults emerged. After emergence, the adults were counted.

Because the peanut pods appeared to very quickly absorb the water containing the WP formulation, possibly causing uneven application, additional 500-g samples of peanuts were sprayed with Dipel WP at 125 mg/20 ml of water per kg. The peanuts were spread on a tray, sprayed with half the suspension, mixed, and then sprayed with the remaining half of the suspension and mixed again. For comparison, other samples were treated by pipetting the suspension over the peanuts and mixing as in the aforementioned treatment. Untreated peanuts were used as checks. Three replicate jars were prepared for each treatment, infested with 100 Indianmeal moth eggs per jar, and held until adults emerged.

To determine whether treatment of only the top layer of peanuts might be effective in preventing infestation as found earlier in grain (McGaughey 1976), samples of peanuts were treated in jars with WP at 625 mg/20 ml of water per kg or dust at 125, 250, or 500 mg/kg and layered above untreated peanuts to depths of 10.2, 20.3, and 30.5 cm in metal cylinders 15.2 cm in diameter by 61 cm high. For the WP, three replicate cylinders were prepared for each treatment depth. For the dust, two replicate cylinders were prepared for each dosage and depth (except as otherwise noted in Table 2), and in addition, cylinders completely filled with treated peanuts were prepared for comparison. Cylinders filled with untreated peanuts (ca. 3.75 kg) were prepared as checks. One hundred eggs of both insect species were added to each cylinder. The cylinders were held at 25°C and 65% RH until adults emerged. After emergence, the adults were identified and counted.

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Based on the results of the previous tests, equivalent dosages of the two formulations were selected for more thorough testing in larger fiber drums (47 cm in diameter by 71 cm deep) containing ca. 36 kg of peanuts. A lower volume of water was used for applying the WP, and deeper layers of treated peanuts were used for both formulations. Treated peanuts (ca. 30 kg) were layered 50.8 cm deep over 10.2 cm of untreated peanuts (ca. 6 kg) in each drum. The WP was applied at 50 mg/1.39 ml of water per kg of peanuts by spreading the peanuts on a polyethylene sheet (3 by 3 m), spraying half the suspension on with a hand sprayer, mixing the peanuts, and then spraying the remainder on and mixing again. The dust was applied at 200 mg/kg and mixed with the peanuts in a drum that was rolled ca. 2 min, tumbled end-over-end several times, and then rolled for an additional 2 min. Drums of untreated peanuts were prepared for checks. Four replicate drums were prepared for each treatment, infested with 500 eggs of both species per drum, and held until adults emerged. When second-generation adults began emerging in the check drums (ca. 90 days), the test was terminated by fumigating all the drums, and a 500-g sample of peanuts was removed from the top and bottom of each drum for assessment of insect feeding damage. The percentages of insect-damage peanuts were determined for (1) the loose peanuts in each 500-g sample, (2) the peanuts from cracked and broken pods in 200-pod samples, and (3) the peanuts from unbroken or uncracked pods in 200-pod samples.

Results and Discussion

The WP formulation did not completely control Indianmeal moths or almond moths at any of the dosages tested (Table 1). The 375- and 625-mg/kg rates did provide levels of control in the same range as those reported by McGaughey (1976) for rates of 100 to 125 mg/kg on grain. The dust formulation, however, provided virtually complete control at 500 mg/kg, a rate and control level consistent with the earlier data on grain.

When WP suspensions were poured onto the peanuts, the liquid appeared to be immediately absorbed by the pods and not extensively distributed through the peanuts by subsequent mixing. However, spraying the suspension evenly onto all the peanuts did not produce a higher level of Indianmeal moth control than by pipetting the suspension. Dipel WP at 62.5 mg/10 ml of water per 500 g of peanuts produced 84% mortality (SD = 2.9) when sprayed on and 88% (SD = 2.3) when pipetted on (untreated check = 56% mortality, SD = 10.4). Thus, excessive retention of the liquid suspension by the pods appears to occur regardless of how it is applied. This results in poor insect control because the larvae prefer to feed on the loose peanuts and peanuts in broken pods where coverage is less.

Surface layer treatment with the WP formulation was less effective than reported for grain (McGaughey 1976), even though the dosage used here was five times as high (Table 2). Also, little difference was observed between the 10-, 20-, and 30-cm treatment depths in this test. The dust formulation provided good insect control when tested as a surface layer treatment in the metal cylinders (Table 2). The 20- and 30-cm deep layers provided almost complete control of Indianmeal moths even at a dosage of 125 mg/kg. However, higher rates were needed to control the almond moths. Both species were controlled by the lowest dosage when all the peanuts were treated.

In the final test, the dust and WP formulations were compared at equivalent dosages in larger fiber drums with deeper treated layers. The dust was superior to the WP against both species, although the difference was less with Indianmeal moths than with almond moths (Table 3). The efficacy of the lower dosage in this test is attributed to the greater treatment depth used. This test also showed that, at the level of infestation used, most of the feeding damage was to loose peanuts, with very little damage to peanuts within unbroken pods and intermediate damage to peanuts within cracked and broken pods (Table 4). Therefore, if the formulation is to be effective it must protect the exposed peanuts. The dust did so, protecting the loose peanuts significantly better than the WP. The WP permitted extensive and probably unacceptable damage to loose peanuts. The dust also virtually eliminated damage to peanuts within both cracked and unbroken pods, but because the levels of damage to these peanuts were so low, the differences between the dust and WP were not statistically significant (Table 4). There were no statistically significant differences between damage levels at the top and bottom

Table 1.–Moth control using Dipel WP and Top-Side Dipel dust in 500-g samples of inshell peanuts stored in 3.8-liter jars

Formulation	Dosage (mg/kg)	Avg % mortaility of[a]: Indianmeal moth	Almond moth
Untreated		57 ± 5.4	53 ± 5.3
Dipel WP	125 mg	82 ± 3.8	80.25 ± 5.0
	375 mg	93.5 ± 2.1	93.75 ± 1.5
	625 mg	95.25 ± 2.6	98 ± 0.8
Top-Side Dipel dust	500 mg	99.75 ± 0.5	99.5 ± 0.6
	1,500 mg	100 ± 0	100 ± 0
	2,500 mg	100 ± 0	100 ± 0

[a]Means of four replications ± SD; 100 eggs per jar and separate jars for each insect.

Table 2.–Moth control using Dipel WP and Top-Side Dipel dust in metal cylinders (15 by 61 cm) of inshell peanuts[a]

Moth	Depth of treated layer (cm)	Avg % mortality at doses of (mg/kg):			
			Dust		
		WP; 625	500	250	125
Almond moth[b]	10.2	83	86.5	77	69.5
	20.3	87.7	94.5	88	84
	30.5	87.3	98.5	94	90.5
	All treated			99.5	99.5
Indianmeal moth[c]	10.2	93	96	95	91
	20.3	92.7	99	99	99.5
	30.5	92.3	100	98.5	98.5
	All treated			100	100

[a]Means of three replications per dosage for the WP and two for the dust.
[b]Check mortality = 55.3% (six replications).
[c]Check mortality = 67% (six replications).

Table 3.–Moth control using Dipel WP and Top-Side Dipel dust on inshell peanuts stored in drums 47 cm in diameter by 71 cm deep[a]

Treatment	Indianmeal moth		Almond moth	
	Avg no. of adults	Avg % mortality	Avg no. of adults	Avg % mortality
Untreated	123.5	75.3a	198.75	60.3a
Dipel WP (50 mg/1.39 ml/kg)	36.75	92.7b	115.75	76.9b
Top-Side Dipel dust (200 mg/kg)	1.75	99.7c	18.0	96.4c

[a]Means of four drums (replications) per treatment. For each insect species, means followed by the same letter do not differ significantly ($P = 0.05$, by Duncan's multiple range test).

Table 4.–Indianmeal moth and almond moth larval damage to *B. thuringiensis*-treated inshell peanuts in drums 47 cm in diameter by 71 cm deep[a]

Treatment	Sample position	Loose peanuts[b]		Inshell peanuts[c]			
				Broken and cracked pods		Unbroken pods	
		Avg no.	% Insect damaged	Avg no. of peanuts	% Insect damaged	Avg no. of peanuts	% Insect damaged
Untreated	Top	133	70.0	296	19.5	54	1.8
	Bottom	102	64.2	297	9.8	55	1.0
	Avg		67.1a		14.6a		1.4a
Dipel WP (50 mg/1.39 ml per kg)	Top	121	23.0	302	2.8	46	1.2
	Bottom	147	21.5	314	3.0	46	0.5
	Avg		22.2b		2.9b		0.9a
Top-Side Dipel dust (200 mg/kg)	Top	217	2.5	283	0	59	0
	Bottom	184	4.8	294	0.8	58	0
	Avg		3.6c		0.4b		0a

[a]Means of four drums (replications) per treatment. For each category of peanuts, means followed by the same letter do not differ significantly ($P = 0.05$, Duncan's multiple range test).
[b]Per 500-g sample.
[c]200-pod sample.

of the drums, except for peanuts within broken pods in the checks. No reason is apparent for this exception.

The results of these tests showed that both formulations of *B. thuringiensis* reduce insect feeding damage and moth emergence in peanuts. However, the dust consistently reduced moth emergence more and protected the peanuts better than the WP. Better coverage of the peanuts is the probable cause of the greater efficacy of the dust.

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REFERENCES CITED

Kellen, W. R., D. K. Hunter, J. E. Lindegren, D. F. Hoffmann, and S. S. Collier. 1977. Field evaluation of *Bacillus thuringiensis* for control of navel orangeworms on almonds. J. Econ. Entomol. 70: 332–334.

McGaughey, W. H. 1976. *Bacillus thuringiensis* for controlling three species of moths in stored grain. Can. Entomol. 108: 105–112.

1978. Moth control in stored grain: efficacy of *Bacillus thuringiensis* on corn and method of evaluation using small bins. J. Econ. Entomol. 71: 835–839.

1980. *Bacillus thuringiensis* for moth control in stored wheat. Can. Entomol. 112: 327–331.

Pinnock, D. E., and J. E. Milstead. 1972. Evaluation of *Bacillus thuringiensis* for supression of navel orangeworm infestation of almonds. J. Econ. Entomol. 65: 1747–1749.