

Susceptibility of Angoumois Grain Moths¹ to *Bacillus thuringiensis*^{2,3}

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ABSTRACT

Larvae of *Sitotroga cerealella* (Olivier) were susceptible to *Bacillus thuringiensis* Berliner incorporated into a ground diet in gelatin capsules. Doses of 125 and 250 µg of formulated *B. thuringiensis*/g of diet gave 90–100%

control. On wheat, *B. thuringiensis* did not significantly reduce F₁ adult emergence but the 2nd generation was significantly reduced.

Effective and long-lasting control of the Indian meal moth, *Plodia interpunctella* (Hübner), and the almond moth, *Cadra cautella* (Walker), 2 of the 3 major lepidopteran pests of stored grain in the USA, may be possible with formulations of *Bacillus thuringiensis* Berliner (McGaughey 1976, Kinsinger and McGaughey 1976). However, the material gave poor control of the 3rd major pest, the Angoumois grain moth, *Sitotroga cerealella* (Olivier) (McGaughey 1976, Steinhilber and Bell 1953). Since the larvae of this species enter the grain kernels immediately following eclosion and remain there throughout the remainder of preadult life, McGaughey (1976) speculated that these insects could have only brief exposure to the bacterial formulation on the kernel surface. Thus, complete control would be unlikely even if the larvae were susceptible. The study reported here was made to determine whether the larvae were in fact susceptible to formulations of *B. thuringiensis* and whether the low levels of control were the result of the feeding habits. Mortality on treated grain also was further evaluated.

METHODS AND MATERIALS.—The susceptibility of the larvae was determined by incorporating a *B. thuringiensis* formulation containing spores and crystals (Dipel®) into diet consisting of ground whole wheat, corn meal, glycerol, honey, ground dog meal, brewers yeast, ground whole oats, and ground wheat germ (diet No. 3 of Chippendale 1970). The Dipel was labeled as containing at least 25 billion viable spores/g and 16,000 International Units of Potency (*Trichoplusia ni* (Hübner))/mg. The *B. thuringiensis* powder was incorporated into a quantity of dry ingredients at a rate calculated to achieve 1000 µg of powder/g wet weight of the diet. This preparation was then serially diluted with additional (untreated) dry ingredients and mixed by tumbling in a small (150 ml) glass jar. Then the glycerol and honey were incorporated and the treated diet was packed into No. 3 gelatin capsules (2/3 full, ca. 150 mg), and a single Angoumois grain moth egg was placed in each cap-

sule. Fifty capsules of treated diet were prepared for each of the 10 doses that were tested. One hundred capsules were prepared with untreated diet for checks.

Mortality of Angoumois grain moths on wheat was determined by treating 1500-g lots of grain with aqueous suspensions of *B. thuringiensis* at a rate of 2 ml/100 g. Formulation was suspended in water at a concentration calculated to achieve a dose of 600 µg/g, and 3 dilutions were made for the lower doses (450, 300, and 150 µg/g). After the suspensions were poured onto the wheat in glass jars, the jars were tumbled until all moisture was absorbed. A water-treated check was used. Each 1500-g lot was divided into 3 samples, and 25 Angoumois grain moth eggs were placed on each sample in glass jars.

Eggs of the Angoumois grain moth were obtained from the laboratory culture by suspending double strips of black paper in jars containing adults (Ellington 1930). Since the eggs were deposited between the strips, the strips could be separated and individual eggs removed for use in the gelatin capsules. For tests in wheat, small pieces that bore 25 eggs were cut from the strips and placed in the jars so it would be possible to observe the eggs and determine how many hatched.

Capsules and jars were held at 65±5% RH and 25°±1°C until the the adult insects emerged. Percentage mortality in treated samples was compared with that in untreated samples to determine the level of susceptibility.

RESULTS AND DISCUSSION.—The results of the 1st test (Table 1) showed that Angoumois grain moth larvae were susceptible to *B. thuringiensis*: 125–250 µg of formulation/g of diet gave 90–100% control. Mortality of only 50–60% was previously reported for similar doses of the same formulation on corn (McGaughey 1976).

The LC₅₀ calculated from the dosage-mortality data (Table 1) was 17.43 µg/g, with 95% confidence limits of 13.04 and 23.18 µg/g. The slope of the dose-mortality line was 1.50, and the intercept was 3.14.

The test in wheat (Table 2) showed that 600 µg of formulation/g of diet did not significantly reduce adult emergence (*P*=0.19). This result is in general agreement with earlier findings (McGaughey 1976). However, in this test, the adults that emerged were allowed to deposit eggs and die before they were removed. We found that the number of F₂ adults that emerged per F₁ generation adult was reduced by ca.

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Table 1.—Percentage mortality of Angoumois grain moths in capsules of diet treated with *Bacillus thuringiensis* (corrected for 22% mortality in check).^a

Dose ($\mu\text{g/g}$)	Corrected % mortality
1.95	15
3.91	15
7.81	21
15.62	49
31.25	62
62.50	77
125.00	90
250.00	100
500.00	100
1000.00	100

^a Capsules were individually infested with eggs and mortality was based on the failure of adults to emerge. 100 capsules were used for the check and 50 for each dose.

$\frac{2}{3}$ in relation to the controls at all treatment levels ($P < 0.05$). The reason for this reduced rate of population increase on *B. thuringiensis*-treated grain was not apparent, but *B. thuringiensis* may provide greater benefits than are apparent in the 1st generation. Possibly the applications of *B. thuringiensis* to stored grain for control of almond moths and Indian meal moths (McGaughey 1976), though they will not eliminate infestations of Angoumois grain moths, will nevertheless substantially reduce the rate of population development and so obviate the need for other control measures.

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Table 2.—Effect of *Bacillus thuringiensis* treatment of wheat on development of Angoumois grain moths.^a

Dose ($\mu\text{g/g}$)	Avg no. eggs hatched	% mortality ^b F ₁ adults	F ₂ adults	
			No./F ₁ adult ^c	% re- duction ^d
0	19	42	42 a	
150	21	45	14 b	67
300	21	63	9 b	79
450	23	64	8 b	81
600	23	61	6 b	86

^a Means of 3 replications; 500 g wheat/replication with 25 eggs/replication.

^b Mortality was based on the failure of adults to emerge. Means were not significantly different ($P=0.19$) by analysis of variance.

^c Means followed by the same letter do not differ at the 5% level of significance by Duncan's multiple range test.

^d Percent reduction in number of progeny as compared with the number in untreated wheat.

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