Susceptibility of *Cadra cautella*[1] and *Plodia interpunctella*[1] to *Bacillus thuringiensis* on Wheat[2,3]

KANAYO F. NWANZE,[4] G. J. PARTIDA,[4,5] and W. H. MCGAUGHEY[6]
Department of Entomology, Kansas State University, Manhattan 66506

ABSTRACT

Doses of 25 and 150 mg/kg of *Bacillus thuringiensis* Berliner controlled 1st instar and mature larvae, respectively, of the Indian meal moth, *Plodia interpunctella* (Hübner), and the almond moth, *Cadra cautella* (Walker), in wheat. No difference in susceptibility, measured by adult emergence, was observed between the 2 species.

Studies have shown that the Indian meal moth, *Plodia interpunctella* (Hübner), and the almond moth, *Cadra cautella* (Walker), are highly susceptible to *B. thuringiensis* Berliner. However, in all cases, either a large or single dose of the pathogen was used on the grain products or only 1 insect stage was used (Kantack 1959, Godavaribai et al. 1962, Loaiza-Mercado 1962). Under such circumstances, it is difficult to evaluate the results and subsequently to estimate the potential of *B. thuringiensis* for controlling populations of the Indian meal moth or almond moth in stored grain. To study susceptibility of their larvae to *B. thuringiensis,* we attempted to determine the optimum dose required to control the pest in whole grain, whether young or old larvae are more susceptible to the pathogen, and differences in susceptibility of the 2 test insect species.

MATERIALS AND METHODS.—The formulation Dipel® (provided by Abbott Laboratories), containing 16,000 IU of potency/mg, was used on wheat samples which consisted of 300 g of whole, hard red winter wheat placed in sterilized wide-mouth 1.06 liter jars. The wheat had been oven-dried to 11% moisture content. The samples were treated with *B. thuringiensis* spore formulation at rates of 25, 50, 100, 150, and 200 mg/kg. Spore suspensions (made in 10 ml of distilled water) were dispensed with a fast-releasing pipette into the grain. The grain was rotated mechanically for 20 min to insure complete coverage. Grain samples used as checks were treated with 10 ml of distilled water. All grain was equilibrated to 13% moisture content within 24 h after being placed in a rearing room held at 27° ± 1°C and 65 ± 5% RH.

Larvae of the Indian meal moth and almond moth were of 2 age groups: 1st instar (0–48 h old) and mature larvae (18–21 days old). To obtain 1st instars, eggs were collected from egg-laying jars as described by Strong et al. (1968) and surface sterilized using the method described by Spitler (1970). The dried filter paper with eggs intact was placed inside a sterilized plastic container and a thin layer of culture medium was then sprinkled over the eggs. After 2 days, young larvae were picked up with a fine camel-hair brush and placed on treated grain.

Cultures to obtain mature larvae were set up as described for the 1st instars, with the exception that the sterilized eggs were placed in a 3.79 liter jar, and 1.42 liters of culture medium was poured over them. Mature larvae, 18 to 21 days old, were collected from the culture medium with feather-weight forceps and placed on treated grain samples. Extreme care was taken not to injure larvae during handling.

Fifty 1st instars and 25 mature larvae of both species were introduced into their respective jars; each dose was replicated 3 times. Results are expressed as percentage of total number of larvae used at each dose. More 1st instar than mature larvae were used because they are more prone to injury during handling. All tests were held in the rearing room. Adult emergence was recorded every other day until no further adults were observed, but recording was stopped short of emergence of the 2nd generation.

RESULTS AND DISCUSSION.—As shown in Table 1, the various treatments considerably reduced adult emergence of Indian meal moth and almond moth. *B. thuringiensis* had a greater effect on 1st instar than on mature larvae. Yamvarias (1962) obtained similar results on *Anagasta kuehniella* (Zeller).

Complete control of 1st instars of the Indian meal moth and almond moth occurred at the 25 mg/kg dose. Although some larvae matured, most were sluggish and shrunken and, after 70 days, they still had not developed into adults in the treated grain. As mentioned by Yamvarias (1962), this indicates that *B. thuringiensis* prolongs larval development if it does not kill the larva.

Adult Indian meal moth emergence in the untreated grain which was initially infested with 1st instars was 76.7%; for almond moths, only 58.0%. The low adult emergence of both species might be attributed to injury during handling or inability of young larvae to penetrate whole wheat kernels. However, 96 and 98.4%, respectively, of the mature larvae emerged as adults (Table 1).

Mature larvae of both species were controlled effectively by the 150 mg/kg treatment, indicating an intoxication gradient at that dosage between young and old larvae. After feeding on treated grain for a few hours, infected mature larvae became slug-

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[4] Res. Asst. and Res. Entomol., respectively, Dep. of Entomol., Kansas State University, Manhattan 66506.
[5] Present address: Plant and Soil Science Dep., California State Polytechnic Univ., Pomona 91768.
[6] Res. Entomol., U.S. Grain Marketing Res. Center, Agric. Res. Serv., USDA, Manhattan, Kans. 66502.

Table 1.—Average % adult emergence of Indian meal moths and almond moths from samples of wheat treated with a *Bacillus thuringiensis* formulation containing 16,000 IU of potency/mg.[a]

Dose (mg/kg)	Avg % adult emergence per replicate	
	Indian meal moth	Almond moth[b]
None	96.0	98.4
25	21.3	29.2
50	14.7	9.2
100	10.7	6.7
150	5.3	2.7
200	0.0	1.3

[a] Three replicates were used for each dose, and 25 mature larvae (18–21 days old) were used/replicate. All tests were held at 27 ± 1°C and 65 ± 5% RH.
[b] First 3 values based on totals of 60, 65, and 65 mature larvae, respectively, for the 3 replications.

gish, turned a dirty pink, and shrank. As the infection continued, dark-brown to black cadavers of the mature Indian meal moth larvae could be seen in the treated grain. We made similar observations in almond moth cultures. Our observations agree with those made previously on the susceptibility of almond moth and Indian meal moth to *B. thuringiensis* (Godavaribai et al. 1962, Loaiza-Mercado 1962, Kantack 1959). In grain treated with 25 and 50 mg/kg, mature larvae of both species appeared weakened, and some finally emerged as undersized adults with deformed wings.

Seventy days after the tests were started, mature larvae and pupae of the 2nd generation of both species were observed in the untreated grain. However, 2nd generation larvae were not observed in the treated grains. That could have been the result of reduced fecundity of adults or the residual action of the insecticide. Although *B. thuringiensis* may not affect egg hatching, subsequent survival and development of neo-natal larvae may be affected (Yamvarias 1962).

A pest-management program using *B. thuringiensis* with a compatible grain protectant could help reduce pest populations. That approach was used by Taylor (1969), who combined γ BHC and *B. thuringiensis* to effect an integrated control program of the pest complex on cowpeas, *Vigna unguiculata* Walp. *B. thuringiensis* used alone or in combination with other chemical insecticides might reduce or eliminate populations of Indian meal moth and almond moth.

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