Field Tests with *Bacillus thuringiensis* Berliner in an Apple Orchard

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The use of preparations of *Bacillus thuringiensis* Berliner (1) for the control of lepidopterous insects has increased in recent years. For example, the results obtained in field trials against the alfalfa caterpillar, *Colias eurytheme* Boisduval, reported by Steinhaus (10) and Stern *et al.* (11), and against the cabbage looper, *Trichoplusia ni* (Hübner), reported by Hall *et al.* (2), are particularly noteworthy. However, as noted by McEwen (5), the foliage-feeding species are more likely to acquire a lethal dose of the bacillus crystals than species that are internal feeders; thus, he considered the codling moth, *Carpocapsa pomonella* (L.), poorly suited for this type of biological control.

In actual field experiments with such a preparation of *B. thuringiensis* (Thuricide®)[2] against foliage and fruit pests of the apple, *Malus sylvestris* Mill., the results have been variable. Jacques (3) found that the codling moth could be controlled effectively but not at the usual levels of commercial control; unprotected foliage feeders such as the fall cankerworm, *Alsophila pometaria* (Harris), were controlled economically, but protected leaf feeders such as the red-banded leaf roller, *Argyrotaenia velutinana* (Walker), were not. Oatman and Legner (8) and Oatman (7) used ryania and Thuricide in combination in a program of integrated control of orchard pests and reported 86-88% undamaged fruit for 2 consecutive years. Defoliation in an apple orchard by the fall cankerworm and the linden looper, *Erranis tiliaria* (Harris), was significantly reduced by applying *B. thuringiensis* sprays (9). Also, according to Legner and Oatman (4), a population reduction in the eye-spotted bud moth, *Spilonota ocellana* (Denis & Schiffermüller), after exposure to *B. thuringiensis*, was accompanied by retarded growth and development of the insect. In another study by Oatman (6), injury from codling moths was 50% lower after treatment with Thuricide than in an untreated check, but economic control was not achieved; it was reported that the material had value as a selective control agent against the red-banded leaf roller and the eye-spotted bud moth. (The increase of phytophagous mites in the treatment plots was an adverse side-effect in his studies.)

Experiments with an improved formulation (1) of *B. thuringiensis* were conducted during the summer of 1966 at Vincennes, Indiana, against codling moth and other apple pests to determine if the extended biological activity reported would give better results than the formulations used previously by other workers.

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2. Mention of a proprietary product does not necessarily imply its endorsement by the U.S.D.A.

Methods

A block of 5 mature Grimes Golden apple trees in an abandoned orchard of 84 trees was sprayed weekly for 16 weeks with Thuricide 90 TS®, a flowable material containing 30 x 10^9 spores/g. Rate of application varied from 1.5 to 21 lb. of formulated material/100 gallons of spray.

Ten gallons of spray were applied to each tree from the ground by using a single-nozzle hand gun attached to a 40-ft. hose of a conventional high-pressure sprayer operating at 600 psi. Applications were begun May 4 when the trees were at the calyx stage and concluded August 16. The rate of application was doubled as the season progressed. Times of application and doses are shown in Table 1. On the day after all applications except those made June 13 and July 19, a randomly-selected sample of 20 leaves was taken from each treated tree and from 3 nearby untreated trees. Each leaf was then infested in the laboratory with 2 laboratory-reared larvae of red-banded leaf rollers and placed on wet sand in red plastic containers that were 13 cm. in diameter and 8 cm. in height. Eight 2-mm. holes were drilled into the tight-fitting lid to permit gas exchange. The leaves were examined at 1- and 7-day intervals to determine the number of healthy, diseased, and dead larvae. Diseased larvae were easily counted because they deteriorated to a blackened, flaccid sac of liquid.

TABLE 1. Mortality of laboratory-reared red-banded leaf roller larvae exposed to deposits of *Bacillus thuringiensis* on field-sprayed apple leaves. (Vincennes, Ind. 1966.)

Date treated	Dose lb./100 gal.	Adusted % mortality[a b]	
		24 hours	1 week
May 4	1.5	13	32
10	2.7	12	65
16	2.7	0	28
23	2.7	2	30
31	2.7	4	29
June 7	5.3	22	42
13	5.3	—	—
21	10.6	8	93
28	10.6	19	91
July 5	10.6	13	82
12	10.6	22	77
19	10.6	—	—
26	10.6	9	81
Aug. 2	21.0	0	86
9	21.0	8	98
16	21.0	16	96

[a] Adjusted by the use of Abbott's formula.
[b] Dash (—) indicates that leaf samples were not taken.

After 6 applications, 2 apples were taken from each of the 5 treated trees and from each of 2 untreated trees for bioassay studies. These apples were impaled on 4-in. wire pins at the calyx end of the fruit and placed upright on a board. Five first-instar codling moth larvae from a laboratory culture were transferred to each apple with a camel's hair brush, and a narrow ring of tanglefoot was placed around the apple's calyx end to prevent their escape. The apples were dissected 1 week later, and a record was made of the number of larval entries, the number of larvae found, and their condition (Table 2).

On August 18, 2 days after the final application, 100 leaves and 100 fruit were picked from each of the 5 treated trees and each of 5 untreated trees. The leaves were examined, and the amount of insect damage was estimated. Also, the fruit was examined externally and then dissected for detailed study. Records made of the type of damage present and the number of codling moth larvae found are shown in Tables 3 and 4.

Results

As indicated in Table 1, red-banded leaf roller larvae that fed on treated leaves had higher mortality than those that fed on untreated leaves; also, rate of application and the degree of mortality had a direct correlation. Although the controls showed considerable mortality at the end of 1 week of laboratory feeding, the percentage efficiency of the treatment ranged from 28 to 98% at the various rates of applications. However, the effects of *B. thuringiensis* deposits on field-sprayed apple fruit against laboratory-reared codling moth larvae (Table 2) were evident only at the higher rates and even then, damage to the apples was not prevented.

The data obtained from the leaf samples collected at the end of the tests (August 18) showed that damage to treated foliage was about half that sustained by untreated foliage (Table 3). However,

TABLE 2. Mortality of laboratory-reared codling moth larvae exposed to deposits of *Bacillus thuringiensis* on field-sprayed apple fruit. (Vincennes, Ind. 1966.)

Treated date	Dose lb./100 gal.	% mortality at one week		Adjusted % mortality[a]
June 21	10.6	60	78	45
July 12	10.6	75	78	12
26	10.6	75	78	12
Aug. 2	21.0	65	86	60
8	21.0	65	84	54
16	21.0	45	68	42

[a] Adjusted by the use of Abbott's formula.

the amount of damage to untreated foliage by foliage feeders was generally moderate, except near feeding colonies of the eastern tent caterpillar, *Malacosoma americanum* (F.), and the fall webworm, *Hyphantria cunea* (Drury). Although both species were present in the treated trees, they were sufficiently controlled by the weekly sprays so that colonies did not persist.

The damage to the fruit by codling moth was reduced by about half in the plot treated with *B. thuringiensis* (Table 4). An average of 9 vacated galleries of the first generation and 26 active second-generation codling moth larvae per 100 fruit were recorded; in the check, the average was 21 vacated galleries and 46 live larvae. The

TABLE 3. Insect damage to foliage of 5 apple trees sprayed weekly with *Bacillus thuringiensis*. (Vincennes, Ind. 1966.)

Characteristic of damaged portion of leaf	Percentage of leaves damaged[a] in	
	Check	Treatment
Removed	55	21
Skeletonized	43	29
Mined	31	11
Stippled[b]	44	48
% of total leaf area damaged	10	4

[a] Average for 100-leaf samples from each of 5 trees. Leaves picked on August 18, 1966, 2 days after final treatment.

[b] Feeding damage by insects and mites with sucking mouthparts.

TABLE 4. Insect damage to fruit from 5 apple trees sprayed with *Bacillus thuringiensis*. (Vincennes, Ind. 1966.)

Type of injury	Percentage of fruits damaged[a] in	
	Check	Treatment
Vacated codling moth galleries	21	9
Codling moth larvae (live)	46	26
Codling moth stings[b]	65	138
Red-banded leaf roller damage	8	9
Plum curculio scars	22	17
San Jose scale damage[c]	8	3
Fruit deformation[d]	3	2

[a] Average for 100 fruit from each of 5 trees. Fruit picked August 18, 2 days after final treatment.

[b] Characterized by shallow feeding area, corky tissue, growth distortion, and absence of live larvae.

[c] Presence of scale and/or characteristic ring of abnormal color.

[d] Malformed fruit resulting from early season feeding by aphids.

treated fruit had a greater number of stings than the check fruit, which may reflect the death of newly-entered larvae. The fruit in the check had an average of 22% damage by plum curculio, *Conotrachelus nenuphar* (Herbst), adult feeding and oviposition scars, as compared to 17% in the treatment. San Jose Scale, *Aspidiotus perniciosus* Comstock, was also more common on the check fruit, with an 8% infestation, than on the treated fruit, with 3% infestation.

Thuricide 90 TS, in these tests, did not provide sufficient protection of fruit or foliage from insect attack, judged by present economic standards. However, the formulation could be incorporated into an integrated program in which partial control of the codling moth and red-banded leaf roller would be acceptable if other control methods were concurrently directed toward these species.

The results of these tests and of those reported in the literature indicate that the best utilization of the material could be made in a program of selective reduction of lepidopterous foliage feeders, especially such gregarious feeders as tent caterpillars, fall webworms, and, perhaps, leaf rollers, combined with an overall program of biological control or integrated biological and chemical control.

Literature Cited

1. Anonymous. 1965. Thuricide 90 TS flowable extended activity microbial insecticide. Bioferm Division, International Mining & Chem. Corp., 9 pp.
2. Hall, I. M., R. L. Hale, H. H. Shorey, and K. Y. Arakawa. 1961. Evaluation of chemical and microbial materials for control of the cabbage looper, J. Econ. Entomol. **54**(1):141-6.
3. Jacques, R. P. 1961. Control of some lepidopterous pests of apple with commercial preparations of *Bacillus thuringiensis* Berliner. J. Insect Pathol. **3**:167-82.
4. Legner, E. F., and E. R. Oatman. 1962. Effects of Thuricide on the eye-spotted bud moth, *Spilonota ocellana*. J. Econ. Entomol. **55**(5):677-8.
5. McEwen, F. L. 1960. Microbial insecticides for insect control in Handbook of Biological Control of Plant Pests. Plants and Gardens **16**(3):69-75.
6. Oatman, E. R. 1965. The effect of *Bacillus thuringiensis* Berliner on some lepidopterous larval pests, apple aphid and predators, and on phytophagous and predacious mites on young apple trees. J. Econ. Entomol. **58**(6):1144-7.
7. Oatman, E. R. 1966. Studies on integrated control of apple pests. J. Econ. Entomol. **59**(2):368-73.
8. Oatman, E. R., and E. F. Legner. 1962. Integrated control of apple insects and mite pests in Wisconsin. Proc. N.C. Branch E.S.A. **17**:110-5.
9. Quinton, R. J., and C. C. Doane. 1962. *Bacillus thuringiensis* against the fall cankerworm, *Alsophila pometaria*. J. Econ. Entomol. **55**(4):567-8.
10. Steinhaus, E. A. 1951. Possible use of *Bacillus thuringiensis* Berliner as an aid in the biological control of alfalfa caterpillar. Hilgardia **20**(18): 359-81.
11. Stern, V. M., I. M. Hall, and G. D. Peterson. 1959. The utilization of *Bacillus thuringiensis* Berliner as a biotic insecticide to suppress the alfalfa caterpillar. J. Insect Pathol. **1**:142-51.