Figure 1. Larvae of the forest tent caterpillar. Note the gregarious behavior.

Control of the Forest Tent Caterpillar With Microbial Agents

R. D. Frye and David Ramse

Both chemical and biological agents were used in replicated laboratory and field tests for control of the forest tent caterpillar, Malacosoma disstria Hubner. All of the control agents used in these tests except the virus material provided significant reductions in caterpillar numbers.

The forest tent caterpillar, *Malacosoma disstria* Hubner (Figure 1), is a defoliator of many species of trees and shrubs in forested areas. When it increases to outbreak proportions, host plants in large areas are often denuded (Figure 2). Caterpillars are a source of irritation to humans when the larvae and their droppings fall on them and their food. The following study was conducted during 1970 and 1971 in the laboratory and in an area near Fort Totten, North Dakota, including Sully's Hill National Game Preserve. Control of the caterpillar with conventional chemical insecticides is not permitted in the preserve. The purpose of the investigation was to determine if a practical degree of caterpillar control could be obtained with microbial control agents, primarily the bacterium, *Bacillus thuringiensis* Berliner.

Dr. Frye is associate professor, Department of Entomology, and Ramse is a research specialist, Komuge Development Scheme, Musoma, Tanzania.

Procedures

Approximate appearance times of the developmental stages of *M. disstria* were recorded during 1970 and 1971. Plants on which caterpillars were found were identified and listed.

Unreplicated laboratory and field tests in 1970 indicated that several preparations of *B. thuringiensis* were effective in reducing numbers of *M. disstria.* Following the 1970 studies, controlled, replicated tests using *B. thuringiensis* and a polyhedrosis virus against the caterpillars were conducted in the laboratory and field in 1971. The following discussion describes the 1971 tests.

In the laboratory, preparations containing *B. thuringiensis* were applied to a meridic diet described by McMorran (1956). Test larvae were exposed to the treated diet. The anti-microbial agents (formalin, methyl parahydroxybenzoate and aureomycin) were eliminated since the active portion of most of the treatments was *B. thuringiensis.* The diet was poured into petri dishes and allowed to solidify. Each treatment was topically applied to the solidified diet and was replicated five times. Eight 2nd to 4th instar larvae were placed in each dish. The plates were incubated at room temperature under sterile conditions. Numbers of dead larvae were recorded after 24 and 72 hours. Larvae for the laboratory test were reared according to methods described by Addy (1969).

Figure 2. Basswood defoliated by the forest tent caterpillar, Fort Totten, North Dakota, 1970-1971.

Table 1. Development of Malacosoma disstria, Fort Totten, North Dakota, 1970-1971.

Event	1970	1971
Hatching (began)	May 21	May 8
Pupation (began)	June 30	June 23
Adult emergence (between)	July 17-30	July 9-Aug. 16

Lumite® screen sleeve cages, approximately 1 foot in diameter and 2 feet long, were used in a second test. The cages were placed over foliage on green ash trees in the field. The foliage was sprayed with a hand sprayer to the point of runoff. Each treatment was replicated four times and was applied before the sleeve cages were placed over the foliage. Thirty caterpillar larvae were placed in each cage. Larval maturity varied between the 2nd and 5th instars; the majority were in the 3rd and 4th instars. Counts of living and dead larvae were taken after 96, 120 and 192 hours of exposure to the treatments.

Following the sleeve cage test, a test using single, whole trees and treatments similar to those used in the sleeve cage test was conducted in the field. Forty-two basswood trees were selected in a 10-acre area. The trees had an average height of approximately 20 feet. Each treatment was replicated six times.

Treatments were applied with a portable hydraulic sprayer. Five gallons of spray were used for each treatment; approximately 0.8 gallon of spray was applied to each tree. Spraying was sustained for one minute per tree to the point of runoff from the foliage. The maximum vertical reach of the spray pattern was 20 feet and was adequate for good coverage of trees used in the test. Larval counts were made five days after the treatments were applied. Pyrethrum mixed at the rate of 60 ml. per gallon of water was used to dislodge living

Table 2. Host plants of Malacosoma disstria, Fort Totten, North Dakota study area, 1970-1971.

Host	Defoliation rating[a]
Overstory Species	
Tilia americana L. (Basswood)	5
Fraxinus pennsylvanica Marsh. (Green ash)	4
Betula papyrifera Marsh. (Paper birch)	4
Salix amygdaloides Anders. (Peach leaved willow)	3
Populus tremuloides Michx. (Trembling aspen)	2
Quercus macrocarpa Michx. (Bur oak)	2
Ulmus americana L. (American elm)	2
Populus deltoides Marsh. (Cottonwood)	1
Acer negundo L. (Boxelder)	1
Understory Species	
Prunus virginiana L. (Chokecherry)	4
Prunus pennsylvanica L. (Pin cherry)	3
Amelanchier alnifolia Nutt. (Juneberry)	2
Symphoricarpos occidentalis Hook. (Snowberry)	2
Shepherdia argentea Nutt. (Buffaloberry)	2
Lonicera dioica L. (Honeysuckle)	1
Aralia nudicaulis L. (Wild sarsaparilla)	1
Toxicodendron radicans (L.) Kuntze. (Poison ivy)	1
Vitis vulpina L. (Wild grape)	1
Ribes missouriense Nutt. (Gooseberry)	1
Lathyrus ochroleucus Hook. (Peavine)	1
Parthenocissus inserta Kerner. (Virginia creeper)	1
Rhus glabra L. (Smooth sumac)	1

[a]*Key to defoliation:*

Category	Rating
No defoliation	1
Light defoliation (less than 10% of foliage eaten)	2
Moderate defoliation (10-35% of foliage eaten)	3
Heavy defoliation (35-75% of foliage eaten)	4
Severe defoliation (75-100% of foliage eaten)	5

larvae from the trees selected for sampling. Each tree was sprayed with pyrethrum for one minute. After a subsequent 10-minute period, larvae which had fallen onto a 6-foot square tarp placed under the base of each tree were counted; results were evaluated on the basis of the counts.

Results and Discussion

Development

Dates of hatching, pupation and adult emergence for 1970 and 1971 are shown in Table 1.

Differences in development between 1970 and 1971 could have been due to several factors. Weather plays a substantial role in the survival and prosperity of *M. disstria* and may help determine the success or collapse of an outbreak population. Insect development occurred earlier in 1971 than in 1970. Temperatures during the spring of 1971 were generally warmer than during the same period in 1970. There was considerably less precipitation during May in 1971 than during May in 1970. However, two more inches of rain fell during June, 1971 than during June, 1970.

Host plants

Although the study area contained a large number of aspen, *Populus tremuloides* Michx., a highly preferred host, the major host of *M. disstria* in the study area was basswood, *Tilia americana* L. Buffaloberry, *Shepherdia argentea* Nutt., was fed upon to some degree; Stehr and Cook (1968) reported that *M. disstria* avoided *Shepherdia canadensis* (L.). Boxelder, *Acer negundo* L., was almost totally avoided during the 1970-1971 seasons. Observed host plants and defoliation ratings are recorded in Table 2. Some of the more common, non-host species in the area also are included in the list.

Insecticide Tests

Results of the exposure of *M. disstria* to treatments applied to a synthetic diet are shown in Table 3. One pound of carbaryl (Sevin) induced the highest mortality. Two quarts of Thuricide 90TS, 1.5 pounds Biotrol 183 plus Savol, one pound of Biotrol XK plus Savol, two quarts of Thuricide SS, and one pound of Sevin all caused higher than 50 per cent mortality in 24 hours. There was no significant difference among the five treatments. After 72 hours, there were no significant differences between any of the treatment means. This indicates that if time is not critical, any of the treatments could be used to control *M. disstria*. Observations during the above test showed that smaller larvae were more susceptible to treatments with *B. thuringiensis* than were older larvae.

Results of micro-injection of *B. thuringiensis* into the gut of *M. disstria* confirmed that the bacterium will cause mortality of the caterpillars.

Table 3. Mortality of Malacosoma disstria exposed to insecticide treatments on a meridic diet for 24 hours in the laboratory, 1971.

Treatment	Equivalent rate of product per acre	Mean[1,2] mortality
Untreated diet		1.0
Biotrol 183	3.0 lbs.	3.6 a
Biotrol XK	3.0 lbs.	4.0 a
Biotrol XK	1.0 lb.	4.6 b
Thuricide 90TS	2.0 qts.	6.0 b c
Biotrol 183 plus Savol[3]	1.5 lbs.	6.6 c
Biotrol XK plus Savol[3]	1.0 lb.	7.0 c
Thuricide SS	2.0 qts.	7.0 c
Carbaryl (Sevin)	1.0 lb.[4]	7.6 c

[1]*Means followed by the same letter do not differ significantly at the 5% level of error.*

[2]*Number of dead larvae out of 8.*

[3]*A crop oil and surfactant used at an equivalent of 10 gallons per acre.*

[4]*Pounds of actual insecticide per acre.*

Thirty 5th instar larvae were treated with *B. thuringiensis* var. *kurstaki* June 18, 1971. For a control, 30 additional larvae were injected with a saline solution. Two of the 30 treated larvae were alive 72 hours after injection. Twenty-six of the larvae injected with the saline solution were alive.

Results of the sleeve cage test after 96 and 192 hours are shown in Table 4. The polyhedral virus treatment was not significantly different from the control after 96 hours. The virus was not as effective as *B. thuringiensis* when larval mortality was evaluated at 192 hours. However, in the 96-hour reading, it was as effective as two pounds of Biotrol XK plus Savol which accounted for 50 per cent mortality (15 of 30 larvae dead). After 192 hours, mortality from the virus treatment was significantly different from that in the untreated check. This indicates that it may be a slower acting disease than *B. thuringiensis*. Overall, it was not effective in the tests. An analysis after 120 hours was similar to the 96-hour analysis.

After all three periods of exposure (96, 120 and 192 hours) there were no significant differences in mean mortalities among the *B. thuringiensis* treatments. This is further evidence that Savol did not increase the insecticidal effects of higher rates of Biotrol XK. After longer periods of exposure, one-half pound of Biotrol XK plus Savol caused the highest mortality. On the basis of this test, 0.5 pound of Biotrol XK would be the most economical to use. Reduced control late in the test may be explained on the basis of larval maturity and

Table 4. Mortality of Malacosoma disstria larvae after 96 and 192 hours of exposure to microbial insecticide preparations on green ash foliage under sleeve cages, Fort Totten, North Dakota, 1971.

Treatment	Equivalent rate of product per acre	Mean[1] [2] mortality
After 96 hours[3]		
Untreated check		7.50a
Polyhedral solution[5]		11.50ab
Biotrol XK plus Savol	2.0 lbs.	15.00 bc
Biotrol XK	2.0 lbs.	17.75 c
Biotrol XK plus Savol	1.0 lb.	19.50 c
Biotrol XK	0.5 lb.	21.00 c
Biotrol XK	1.0 lb.	21.25 c
Biotrol XK plus Savol	0.5 lb.	22.50 c
After 192 hours[4]		
Untreated check		10.75a
Polyhedral solution[5]		17.00 b
Biotrol XK plus Savol	2.0 lbs.	23.50 c
Biotrol XK plus Savol	1.0 lb.	24.00 c
Biotrol XK	0.5 lb.	24.25 c
Biotrol XK	1.0 lb.	24.75 c
Biotrol XK	2.0 lbs.	25.00 c
Biotrol XK plus Savol	0.5 lb.	26.50 c

[1]Means followed by the same letter do not differ significantly at the 5% level of error.

[2]Number of dead larvae out of 30.

[3]3.63 inches of rainfall during the interval between treatment application and data recording.

[4]4.57 inches of rainfall during the interval between treatment application and data recording.

[5]A water solution from homogenated M. disstria larvae infected with a polyhedrosis virus; the equivalent rate was not determined.

weather (Table 4, footnotes 3 and 5). Larvae were more mature later in the test and were not feeding as vigorously as they were earlier. Additional rainfall and prolonged exposure to sunlight could have further reduced the number of viable *B. thuringiensis* spores on the leaves. The presence of a fungal disease and parasitism may have influenced earlier results in some cases. Parasitism was not evident early in the test; some of the larvae used at that time were later found to be parasitized. During later stages of the test, some larvae went into the pupal stage and did not become adequately exposed to the treatments. Throughout the 1971 sleeve cage test, some 3rd and 4th instar larvae were observed spinning silken cases, which could have protected them from the treatments.

All of the Biotrol XK treatments provided significant control in the whole tree test in 1972 (Table 5). There were no significant differences among the treatments. However, when the number of caterpillars remaining on the host plants and the dosage of *B. thuringiensis* applied are considered, 0.5 pound Biotrol XK plus Savol proved to be the most desirable treatment. One-half pound of Biotrol XK with Savol was the most consistent treatment in all field tests conducted in 1971.

Table 5. Efficacy of preparations of Bacillus thuringiensis in the control larvae of Malacosoma disstria on basswood, Fort Totten, North Dakota, 1971.

Treatment	Equivalent rate of product per acre	Mean[1] [2]
Biotrol XK plus Savol	0.5 lb.	5.33 a
Biotrol XK	0.5 lb.	5.50 a
Biotrol XK	1.0 lb.	7.50 a
Biotrol XK plus Savol	2.0 lbs.	8.00 a
Biotrol XK	2.0 lbs.	8.17 a
Biotrol XK plus Savol	1.0 lb.	10.83 a
Untreated trees		31.83

[1]Means followed by the same letter do not differ significantly at the 5% level of error.

[2]Average number of living larvae on a 6 foot square tarp placed under each sample tree.

Summary

Outbreak populations of *Malacosoma disstria* Hubner occurred during the summers of 1970 and 1971 in the Sully's Hill National Game Preserve and immediate area. Nearly 1,000 acres of basswood and other tree species were defoliated each year of the outbreak. Weather appeared to influence hatching, pupation and adult emergence. The major overstory host plant for *M. disstria* was basswood. The major understory host plant was chokecherry. Carbaryl (Sevin), Biotrol 183, Biotrol XK, Thuricide 90TS, Thuricide SS and a polyhedrosis virus were tested against the caterpillar in replicated and controlled laboratory and field tests. All but carbaryl and the virus material contain the entomogenous bacterium *Bacillus thuringiensis*. All of the materials, except the virus, provided significant control of the caterpillar. The most consistent treatments were carbaryl at an equivalent of 1 pound of actual toxicant per acre and Biotrol XK plus the crop oil Savol (equivalent of 0.5 lb. of the Biotrol product and 10 gallons of Savol per acre). Savol did not enhance the effect of higher rates of the Biotrol.

References

Addy, N.D. 1969. **Rearing the forest tent caterpillar on an artificial diet.** Econ. Entomol. 62(1): 270-271.

McMorran, A. 1965. **A synthetic diet for the spruce budworm,** Choristoneura fumiferana (Clem.) **(Lepidoptera: Tortricidae).** Can. Entomol. 97: 58-62.

Stehr, F.W. and E.F. Cook. 1968. **A revision of the genus** Malacosoma **Hubner in North America (Lepidoptera: Lasiocampidae): Systematics, biology, immatures, and parasites.** U.S. Nat. Mus. Bull. 276. 321 pp.