COLD FOG APPLICATIONS OF PESTICIDES FOR CONTROL OF *MALACOSOMA DISSTRIA*

by W.T. Johnson[1] and O.N. Morris[2]

Abstract. Tests were conducted to determine the effectiveness of a ULV fog generator in dispersing *Bacillus thuringiensis* and Bt-combinations of synthetic organic insecticides in liquid formulations against the forest tent caterpillar, *Malacosoma disstria.* Those formulations containing superior horticultural oil as the carrier gave better control over those in which water was the sole carrier. The water portion of the mist particle was subject to rapid evaporation and appeared to be a major cause for poor control in the system described. The ULV fogger with some mechanical modifications, can be used effectively for application of microbial insecticides to trees. Thuricide 16B combined with acephate in an oil emulsion carrier was highly effective in reducing tent caterpillar populations.

Evidence has been accumulating for over 20 years to document the effectiveness of *Bacillus thuringiensis* Berliner (Bt), a bacterial pathogen, against a broad array of lepidopterous pests (Harper 1974). The environmental acceptability of this pathogen as a pesticide is also well known. The work of several investigators has produced evidence that Bt efficiency can be increased by the addition of sub-lethal doses of certain chemical insecticides (Benz 1971; Morris 1972; Morris and Armstrong 1975; Morris 1977). The forest tent caterpillar (FTC), *Malacosoma disstria* Hubner, is known to be susceptible to Bt under field conditions (Abrahamson and Harper 1973; Wallner 1971). Bt in field studies or routine forest pest control has been applied by aerial sprays or ground equipment using hydraulic sprayers and mist blowers. Recent investigations (Falcon et al., 1974; Frye et al., 1976; Sorensen et al., 1978) have demonstrated that cold fog generators can be useful tools for Bt dissemination to field crops as well as trees.

The objective of this study was to determine the impact of low dose Bt-chemical pesticide mixtures on *M. disstria* when applied to ash trees, *Fraxinus pennsylvanica*, through a ULV cold fog generator.

Methods and Materials

Test area. A 2-acre block of green ash, *Fraxinus pennsylvanica,* was made available for this study at the Ottawa, Ontario city nursery. Tree size ranged between 6.2 and 7.5 cm dbh and 6.2 to 6.8 m high. Data were taken from 12 test plots containing a total of 108 trees. Each test plot contained 9 trees in 3 rows with 4′ spacing between rows. Each plot was separated from adjacent plots by 6 trees in 2 rows. All trees were in a low state of vigor because of crowding and lack of pest control maintenance. There was a low incidence of forest tent caterpillars (FTC) during 1976 with less than 20 egg bands found in the spring of 1977 from the entire block of trees.

Introduced population. A FTC population was introduced into the nursery from a forest site near the village of Kaladar, Ontario. Twigs with egg bands were collected in late March from trembling aspen, *Populus tremuloides,* and refrigerated at 6°C. On 6 May, after 36 days in storage, the egg bands were attached to the test trees. Four egg bands were tied with horticultural wire to outer branches of each tree, one to each quadrant. The egg bands were sized so that each tree would have an average population of 382 living larvae. To obtain this number, the larvae from 60 egg bands were allowed to hatch in the laboratory with an average emergence of 95.5 per band, thus it was possible to obtain an estimate of the number of larvae per tree at the beginning of the test. These larvae developed normally on the trees with the moult at the end of the 2nd instar occurring about 21 May. Fog treatments were applied while the larvae were in the 3rd instar (25, 26, 27 May 1977).

Phenology. The spring phenological development in the green ash nursery block was approxi-

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mately one week later than in trees inside the city limits due to a temperature differential common in large northern cities. The temperature gradient also allows FTC to develop faster in the city. Egg bands, from the Kaladar population, were attached to the nursery trees after the leaf buds had started to open and the flower buds, both male and female, had fully opened. The small natural population of FTC in the nursery began to hatch at the same time the ash flower buds began to break. This phenomenon started fully 1 week before there was evidence of leaf bud developments. The first instar larvae fed on the flower buds until the leaf buds started to open.

Equipment and fog application. All insecticide mixtures were applied with a Leco ULV Fog Generator, Model HD, normally used for mosquito abatement (Fig. 1). Such machines with air shear nozzles produce droplet sizes that range from 5 to 30 microns (11.7 MMD) with 90 percent of the droplets being between 15 and 20 microns (Fultz et al. 1972). These droplets do not fall within the size range of a fog. Nonetheless the machine is described as a fogger. Droplet velocity at the nozzle of the Leco is 11799 m/s when the liquid pressure is 27.5k PA.* Loss of velocity at various distances from the nozzle has not been determined.

The pesticide tank was modified for agitation of the fogging mixtures. To accomplish this, the tank was mounted on a platform and adjusted to rest on a small laboratory magnetic stirrer. The filter in the tank lines was removed to allow particulate matter (Bt and carbaryl) to flow into the dispersing head.

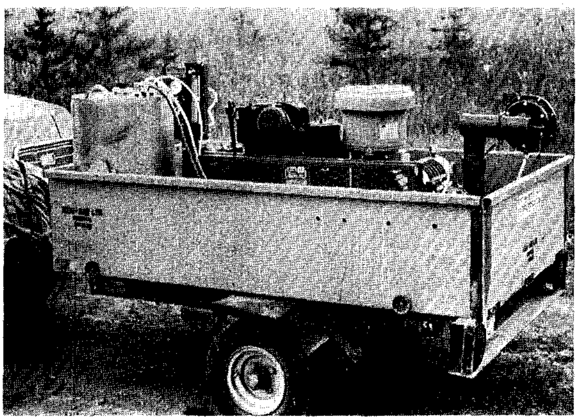

Fig. 1. A Leco cold fog generator in operational position.

The fogger, weighing approximately 202 kg, was mounted on a trailer for towing by a light truck or auto. The fogging operation took place over 3 consecutive days and early in the morning when the air was calm and the relative humidity was high. The fogger was calibrated to deliver approximately 900 ml per minute. Each plot received approximately 61 ml of the fogging suspension. Kromekote® cards were hung in several trees to assess "fog" deposition. Efficacy data were taken at a distance ranging between 8.5 and 12.2 meters from the dispensing head.

Relative humidity and wind speed records were taken at time of treatment; amount of precipitation and hours of bright sunlight were recorded for the 24 hour period following the treatments.

Formulation and diluents. The pesticide ingredients used were *B. thuringiensis* (Thuricide® 16B, Sandoz, Inc.; Dipel®, 36B, Abbott), diflubenzuron (Dimilin®, Thompson Hayward Co.), carbaryl, (Agway, Inc.) and acephate, (Chevron Chemical Ltd., Canada). All fogging mixtures were made up in 7.5 liter quantities and all mixtures containing *Bacillus thuringiensis* were prepared to contain the application equivalent of 2 BIU per acre. Carbaryl and acephate were applied at the rate of 37 grams active ingredient per acre. Diflubenzuron in all solutions was mixed at 100 ppm.

All fogging mixtures contained 0.2% Erio Acid Red XB (Ciba-Geigy) as a dye marker and all Bt mixtures contained 0.2% Uvitex® (Ciba-Geigy) as an ultraviolet protectant. Thuricide mixtures contained 1 part Thuricide 16B, 1 part Volck® spray oil (Chevron Ltd.), 2 parts water plus the dye and ultraviolet protectant. Dipel mixtures contained 1 part Dipel 36B, 34 parts water and 4 grams CMC (Carboxel R-295), Chemical Developments of Canada Ltd., as a suspending agent. Dipel could not be kept suspended in spray oils, thus water was substituted as the carrier.

When carbaryl or acephate were the only active ingredients, water was the sole carrier. All mixtures containing carbaryl were prepared from a sandmilled flowable formulation developed by the

*Lowndes Engineering Co. (Leco Products)

Agway Corporation of Syracuse, N.Y. This product was tested for Bt compatability by a method described by Morris (1977) and found not to interfere with spore germination at field dosages.

Sampling. A census of the larval population density was taken 5 and 12 days after treatment (Table 1) at which times the larvae were in the 3rd and 4th instar respectively. The caterpillars on each tree were easily counted at the first sampling. However, on the second sampling entire colonies in part of the untreated check plot had migrated to adjacent trees because the original host trees were nearly defoliated, causing some interference with data analysis.

Bt spore viability counts were taken from leaves 6 hours and again at 4 days after treatment. In each plot two leaflets were randomly selected from trees in rows 1, 3 and 6. Two discs, 13 mm in diameter, were cut from each leaflet and a viable spore assay test was made by a method described by Pinnock et al. (1971).

Results and Discussion

Biological and behavioral observations. Green ash is an acceptable oviposition tree for FTC according to Sippell's (1957) definition of a host tree. While eggs hatch at least one week before leaf buds break, the larvae readily feed on the flower buds which develop earlier and sustain them until the foliage buds open. As temperature remains cool during much of the 1st and 2nd stadia, growth is slow; however, the development of the insect is closely attuned to the phenology of ash trees.

Larval development on ash follows the pattern described by Sippell (1957). The larvae, after breaking out of their shells, move distally and/or upward until they find flower buds. The entire colonly while in the 1st instar may find ample food in one large flower bud. Some colonies were observed to remain on flower buds for 7 days. If the food source is ample, a colony of 1st instar larvae will not move over 5 cm. When the first food source is exhausted, the larvae withdraw, rest, then seek another feeding site. If food is plentiful through the 3rd instar period, a colony may not move over 100 cm. Moulting of first instar larvae often occurs on leaves and at a lower level than the feeding site. Subsequent moults occur on bark and at successively lower levels of the tree. Except for those periods of moulting and for the last instar, FTC is positively phototropic. They tend to remain high in the tree or with the most luxuriant foliage. Such behavior offers clues to the proper application of spray materials, such as, sprays directed to outer foliage.

Table 1. Treatments for control of the forest tent caterpillar.

	Larvae/tree[a]							
	Post spray		*Corrected % pop. reduction*[b]		*Viable spores/mm*^{2c}		*% Spore*	
Treatments	*+5 days*	*+12 days*	*+5 days*	*+12 days*	*+6 hrs.*	*+4 days*	*loss*	*RH*[d]
Water carrier								
Dipel	122	42	14.7	65.3	10	9	10	30
Dipel-diflubenzuron	72.6	26.8	49.3	81.3	71	4.95	93	58
Dipel-carbaryl	169	64.6		46.7	21.	16	24	33
Dipel-acephate	79	28.5	44.8	76.5	131.5	20	85	46
Carbaryl	32.5	25.3	77.3	79.1	5.8	2.1	63	67
Acephate	49	17	65.8	86.0	.3	.05	83	83
Oil emulsion carrier								
Thuricide	41	6.6	71.4	97.6	132.5	29.5	78	28
Thuricide-diflubenzuron	37	7	74.6	94.3	55.	27	51	28
Thuricide-carbaryl	15	20	89.6	84.4	78	27.5	64	67
Thuricide-acephate	.8	.2	99.4	99.8	676.5	122.0	82	28
Diflubenzuron	127.6	32	10.9	73.6	11.5	4	65	46
Untreated Check	143	121	.26	15.7	3	.35	88	

[a]$\bar{x}$ based on 9 tree replicates. Pretreatment counts average 382 larvae/tree.

[b]Correction by Abbott's Formula

[c]Avg. of 4, 9 mm discs from 2 leaflets

[d]Relative humidity at treatment hour

Microsporidium infection. A large number of the caterpillars brought from Kaladar, Ontario and reared on synthetic media in the lab were heavily infected with a microsporidium, identified by Dr. G.G. Wilson of Insect Pathology Research Institute as *Nosema disstriae* (Thomson). Laboratory rearing was unsuccessful because of microsporidia even though stringent sterilizing procedures were used. Hatching occurred normally, but within 5 to 8 days the larvae refused to eat. The microsporidia counts from the gut increased dramatically, likely because of some unidentified stress in the rearing technique. Caterpillars reared out of doors on natural food survived.

Fogging evaluation. Cold fog generators, because they produce small particles provide excellent pesticide disperson. Guidance, impingement and adherence of fog particles are the key factors limiting the practical use of such generators on plants. The present work confirms some of these problems and suggests possible solutions.

Table 1 summarizes the results of an experiment utilizing 11 pesticide mixtures, applied through a fog generator. In calculating the concentrations of active ingredient for fog mixtures, we attempted to develop mixtures in which the dosage rates of the separate active ingredients would likely be sub-lethal to the FTC if applied alone. This was not achieved. Except for Thuricide-acephate, dosage levels used were apparently not low enough to show distinct additive effects when combined. One of the reasons for the high mortality from calculated "sub-lethal" doses was the matter of deposit. Trees closest to the fog nozzle had substantially fewer larvae than trees further away suggesting greater pesticide deposits on the closer trees.

All Bt mixtures were calculated to contain the same number of spores per unit volume. However, more caterpillars were killed by the Thuricide-acephate combination than by any other treatment (99.4% mortality 5 days after treatment). When percent mortalities from Thuricide and Thuricide-acephate are compared, the addition of acephate increased effectivensss by 28%. Dimilin was also highly effective mainly at the 12 day assessment.

Evaporation of mist particles, containing insecticide blown from airblast machines, has been shown to cause pest control failures (Brann 1965). The Leco fogger was in effect, used as an airblast sprayer and subject to the same failures described by Brann. Evaporation can be reduced by applying pesticides when the relative humidity is high, by adding emulsifiable horticultural spray oil or suspending agents. The effect of these substances on evaporation was monitored by correlating weather data and by using Kromekote® cards suspended in test plot trees as well as adjacent trees. Mist particles rarely impinged beyond 14 m when the fog mixture contained oil and rarely over 9 m when water was the sole carrier. Visually, the fog containing emulsified oil could be easily followed for more than 30 m; water-based fog could be followed about 12 m. Fog passing to and around the dangling, leaflet-shaped Kromekote cards resulted in a differential droplet pattern. The edge of the cards had approximately 25% more spots than the center of the card. If this phenomenon held true on the ash leaves, there would have been a higher concentration of insecticides on the leaf edges, a factor of great importance for edge feeding insects.

Spore counts helped to confirm, albeit circumstantially, that many of the mist particles evaporated before the active ingredients impinged on the leaf. All Dipel and Dipel mixtures (dispersed in water) had low spore counts on leaves when compared to treatments dispersed in oil emulsions. Meteorological conditions were shown to be important where water was the carrier. Low RH correlated with low spore counts on leaves. Acephate gave a high degree of control which can also be correlated with high RH. Meteorological conditions did not appear to have an adverse effect on treatments utilizing the oil emulsion carrier.

Spores found on leaves in plots where Bt was not applied are presumed to be other bacteria, fog drift from other plots or both.

Postmortem Examination. Throughout the test period, sick and dead larvae from the treatment plots were collected to determine the cause of death. Only one dead larva was found in the check plot. Attempts to ascertain the cause of its death were unsuccessful. Nine dead caterpillars were found in the diflubenzuron plot. Eight of these were diagnosed as Bt positive and one microsporidia positive suggesting a low natural incidence of the latter pathogen. No dead larvae in the carbaryl and acephate plots were diagnosed as Bt positive. There were several hundred dead larvae found in the Bt and Bt combination plots. About 5% were diagnosed and all were found to be Bt positive.

Equipment evaluation. This study shows that good dispersion occurs and that a large number of viable Bt spores pass through the air shear nozzle and adhere to the foliage. Fultz et al. (1972) demonstrated the consistency and range of particle size produced by the Leco Model HD cold fogger. Since droplets are produced by an air shear dispersing head, the question must be raised about such action on the character of the emulsified particle. With the mass median diameter of droplets in the range of 11.7μ it is important that the oil portion of the droplet be on the outside to reduce the rate of evaporation while in the air stream. Also, it is well known that impingement of liquid particles is a function of particle size and air stream velocity, therefore studies must be conducted to determine velocity loss characteristics of this machine.

From an operational standpoint, the Leco fogger is not entirely satisfactory for application of "fog" to trees and the dispersion of insoluable particulate matter. "Fog" formulations with insoluable particles like Bt may clog the flow valve, particularly if the machine is shut off for a few minutes. To clean the valve and flow meter is difficult and especially so in a field operation. The nozzle assembly, as with mist blowers, must articulate easily while the machine is in operation. Nozzle articulation in the Leco is awkward. Some design modifications will be necessary to make this machine practical for nursery or tree and shrub maintenance work.

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ABSTRACTS

Chapman, Douglas. 1980. **Junipers thrive in various soils, suit many planting designs.** Weeds, Trees & Turf 19(9): 116-117.

Junipers and Eastern redcedar are extremely tolerant of many urban conditions. They thrive in drought-gravelly soils needing little care if the correct plant is selected. Juniper adds another dimension to our landscape with a narrow-leaf evergreen which thrives under severe winter or summer conditions. The insects and diseases are many, including cedar-apple rust, twig blight (*Phomopsis juniperovora*), webworm, scale, mites, and bagworm, but only a few are catastrophic. The catastrophic pests are twig blight, scale, and mites. The over 170 cultivars available in the trade make this an exciting yet confused group. The discussion of cultivars is designed to assist landscape architects and grounds managers make effective decisions, reducing maintenance while improving the quality of the landscape.

BIRCH, M.C., T.D. PAINE, and J.C. MILLER. 1981. **Effectiveness of pheromone mass trapping of the European elm bark beetle.** California Agriculture 35(1 & 2): 6-7.

From 1976 through 1979 a study was conducted in three isolated eastern California towns to determine whether pheromone mass-trapping could be successfully used to suppress populations of the smaller European elm bark beetle, *Scolytus multistriatus*. Using the synthetic pheromone "multi-lure," we set out baited sticky traps in an attempt to suppress beetle populations. If trap catches truly reflect changes in beetle populations, a mass trapping strategy might work, although the time required before it is effective might be excessively long. In addition to these trapping results, we attempted to estimate the population of beetles independently so that trapping efficiency could be measured directly. A second estimate of trapping efficiency was obtained by releasing a known number of beetles. Of an estimated 46,500 beetles that emerged, approximately 20 percent were recaptured. Thus, all the evidence of comparative trapping and mark/release methods for estimating the effect of our trapping indicate that we were probably monitoring rather than suppressing the local beetle populations. To summarize, pheromone mass-trapping as a means of suppressing beetle populations appears to be ineffective. It is unlikely to succeed biologically or economically without a concurrent and effective sanitation program. Pheromone traps do, however, provide a good reflection of population behavior and can be used effectively to monitor such changes.